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(12) **United States Patent**
Shima

(10) **Patent No.: US 12,137,224 B2**
(45) **Date of Patent: Nov. 5, 2024**

(54) **IMAGE ENCODING APPARATUS, IMAGE DECODING APPARATUS, METHODS FOR THE SAME, AND NON-TRANSITORY COMPUTER-READABLE STORAGE MEDIUM FOR SUPPRESSING THE CODE AMOUNT OF QUANTIZATION MATRICES**

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(73) Assignee: **Canon Kabushiki Kaisha**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 107 days.

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(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. PCT/JP2020/030904, filed on Aug. 14, 2020.

(30) **Foreign Application Priority Data**

Sep. 19, 2019 (JP) 2019-170810

(51) **Int. Cl.**

H04N 19/126 (2014.01)
H04N 19/176 (2014.01)
(Continued)

(52) **U.S. Cl.**

CPC ***H04N 19/126*** (2014.11); ***H04N 19/176*** (2014.11); ***H04N 19/18*** (2014.11); ***H04N 19/186*** (2014.11)

(58) **Field of Classification Search**

CPC H04N 19/126; H04N 19/176; H04N 19/18; H04N 19/186

See application file for complete search history.

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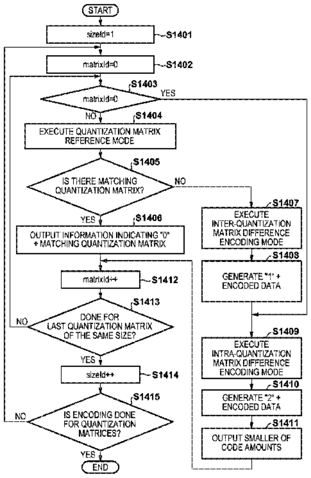
Primary Examiner — James T Boylan

(74) *Attorney, Agent, or Firm* — Canon U.S.A., Inc. IP Division

(57) **ABSTRACT**

An encoding apparatus comprises a quantizer quantizing transform coefficients in a block in an image using a first quantization matrix, and an encoder encoding the first quantization matrix, wherein, for encoding the first quantization matrix, if using a first mode, the encoder encodes information indicating that the first quantization matrix is the same as a second quantization matrix having already been encoded, if using a second mode, encodes a difference between an element of the first quantization matrix and an element of the second quantization matrix, and if using a third mode, encodes a difference between an element and another element within the first quantization matrix, wherein a code amount of information representing the first mode is used is less than that of information representing that the second mode is used.

11 Claims, 19 Drawing Sheets


START
sizeId=1
S1401
matrixId=0
S1402
S1403
matrixId=0
YES
NO
S1404
EXECUTE QUANTIZATION MATRIX REFERENCE MODE
S1405
IS THERE MATCHING QUANTIZATION MATRIX?
NO
YES
S1406
OUTPUT INFORMATION INDICATING "0" + MATCHING QUANTIZATION MATRIX
S1407
EXECUTE INTER-QUANTIZATION MATRIX DIFFERENCE ENCODING MODE
S1408
GENERATE "1" + ENCODED DATA
matrixId++
S1412
S1413
DONE FOR LAST QUANTIZATION MATRIX OF THE SAME SIZE?
NO
YES
sizeId++
S1414
S1409
EXECUTE INTRA-QUANTIZATION MATRIX DIFFERENCE ENCODING MODE
S1410
GENERATE "2" + ENCODED DATA
S1411
OUTPUT SMALLER OF CODE AMOUNTS
S1415
IS ENCODING DONE FOR QUANTIZATION MATRICES?
NO
YES
END

(51) **Int. Cl.**

H04N 19/18	(2014.01)
H04N 19/186	(2014.01)

(56) **References Cited**

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2023/0232003	A1*	7/2023	De Lagrange	H04N 19/126 375/240.03

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FIG. 1

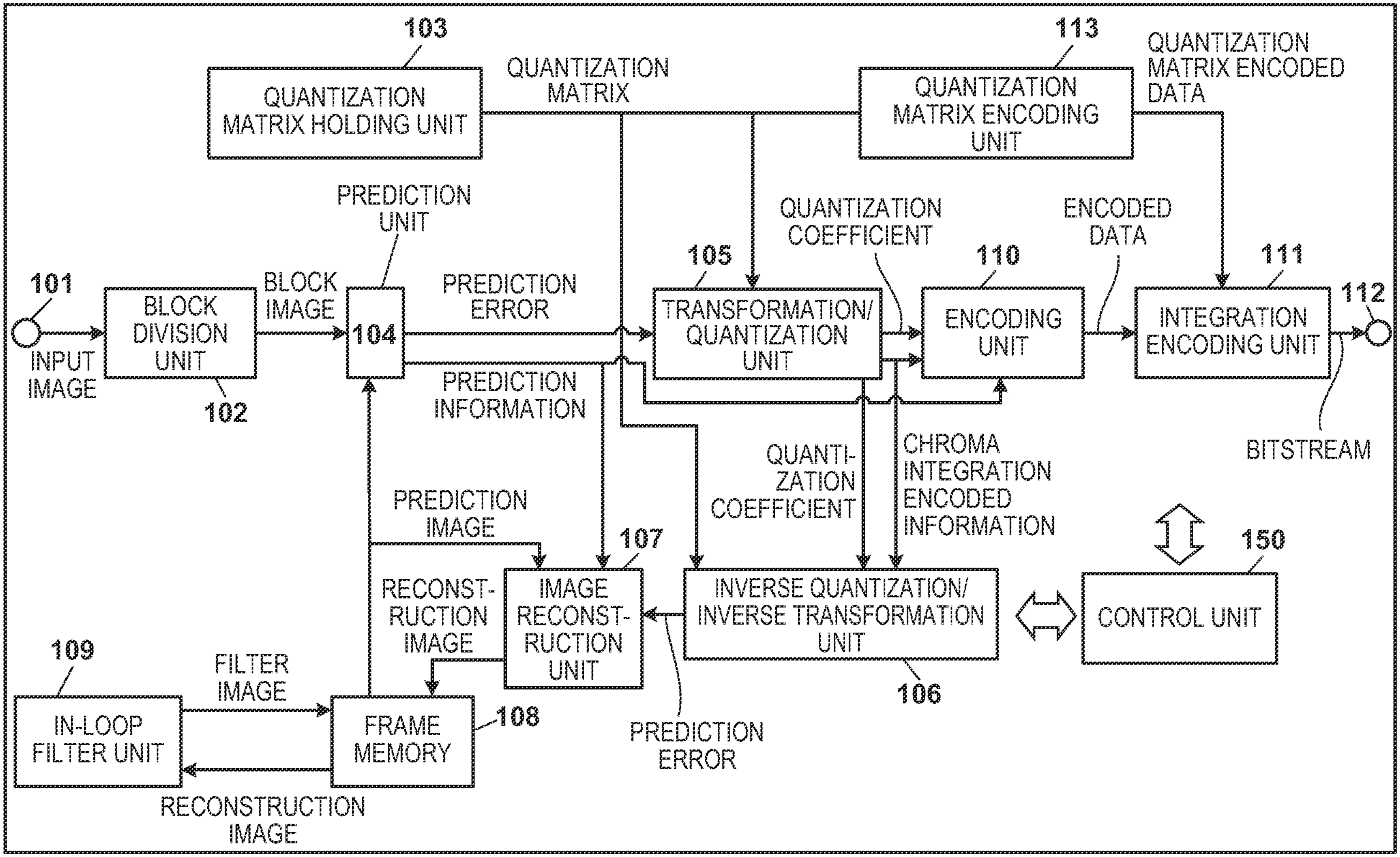

103
QUANTIZATION MATRIX HOLDING UNIT
QUANTIZATION MATRIX
113
QUANTIZATION MATRIX ENCODING UNIT
QUANTIZATION MATRIX ENCODED DATA
PREDICTION UNIT
101
INPUT IMAGE
BLOCK DIVISION UNIT
102
BLOCK IMAGE
104
PREDICTION ERROR
PREDICTION INFORMATION
105
TRANSFORMATION/ QUANTIZATION UNIT
QUANTIZATION COEFFICIENT
110
ENCODING UNIT
ENCODED DATA
111
INTEGRATION ENCODING UNIT
112
BITSTREAM
QUANTI- ZATION COEFFICIENT
CHROMA INTEGRATION ENCODED INFORMATION
PREDICTION IMAGE
107
IMAGE RECONST- RUCTION UNIT
RECONST- RUCTION IMAGE
INVERSE QUANTIZATION/ INVERSE TRANSFORMATION UNIT
106
150
CONTROL UNIT
109
IN-LOOP FILTER UNIT
FILTER IMAGE
FRAME MEMORY
108
RECONSTRUCTION IMAGE
PREDICTION ERROR

FIG. 2

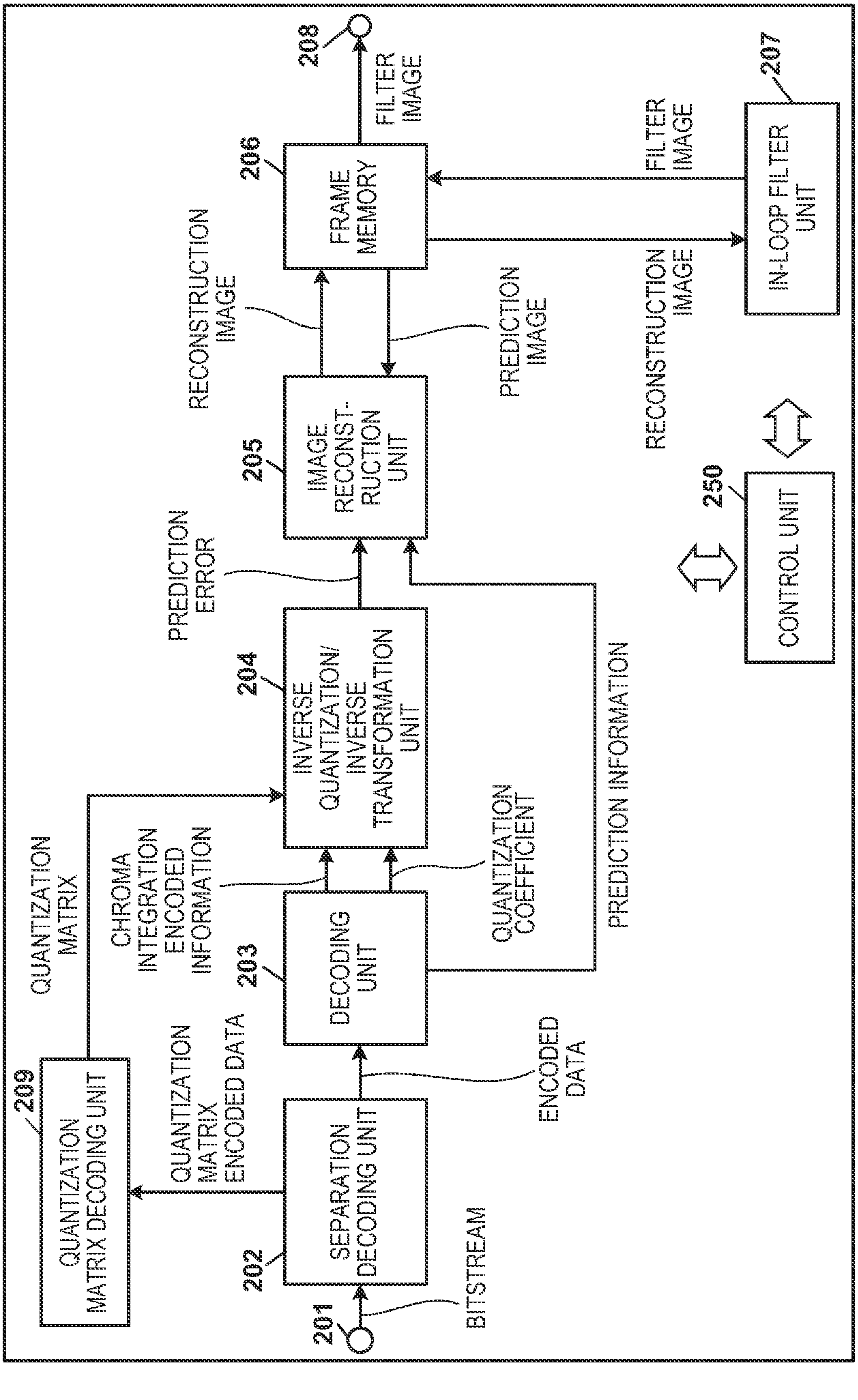

201
BITSTREAM
202
SEPARATION DECODING UNIT
QUANTIZATION MATRIX ENCODED DATA
209
QUANTIZATION MATRIX DECODING UNIT
QUANTIZATION MATRIX
ENCODED DATA
203
DECODING UNIT
CHROMA INTEGRATION ENCODED INFORMATION
QUANTIZATION COEFFICIENT
PREDICTION INFORMATION
204
INVERSE QUANTIZATION/ INVERSE TRANSFORMATION UNIT
PREDICTION ERROR
205
IMAGE RECONST-RUCTION UNIT
RECONSTRUCTION IMAGE
PREDICTION IMAGE
206
FRAME MEMORY
FILTER IMAGE
208
RECONSTRUCTION IMAGE
FILTER IMAGE
207
IN-LOOP FILTER UNIT
250
CONTROL UNIT

FIG. 3

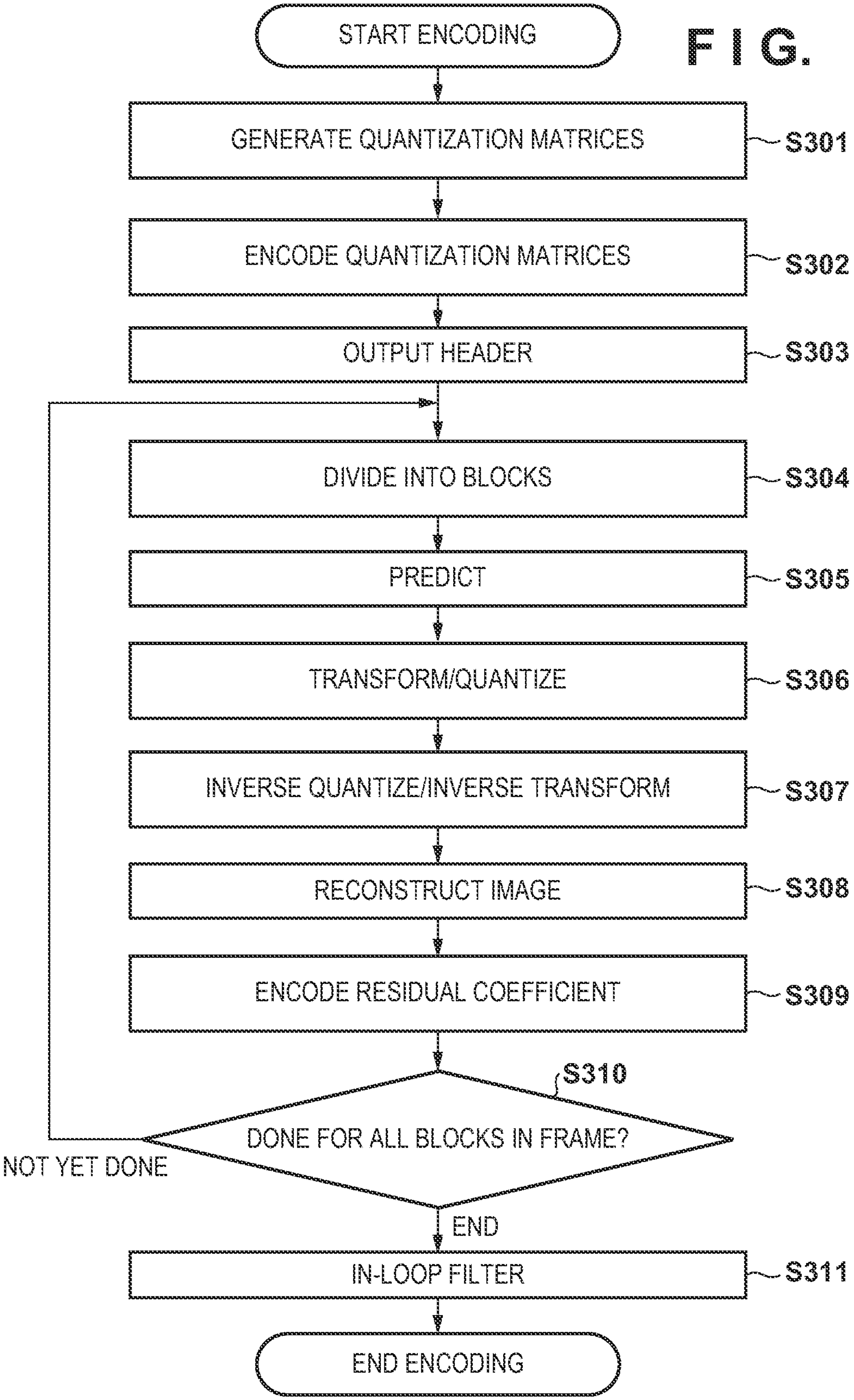

START ENCODING
GENERATE QUANTIZATION MATRICES
S301
ENCODE QUANTIZATION MATRICES
S302
OUTPUT HEADER
S303
DIVIDE INTO BLOCKS
S304
PREDICT
S305
TRANSFORM/QUANTIZE
S306
INVERSE QUANTIZE/INVERSE TRANSFORM
S307
RECONSTRUCT IMAGE
S308
ENCODE RESIDUAL COEFFICIENT
S309
S310
DONE FOR ALL BLOCKS IN FRAME?
NOT YET DONE
END
IN-LOOP FILTER
S311
END ENCODING

FIG. 4

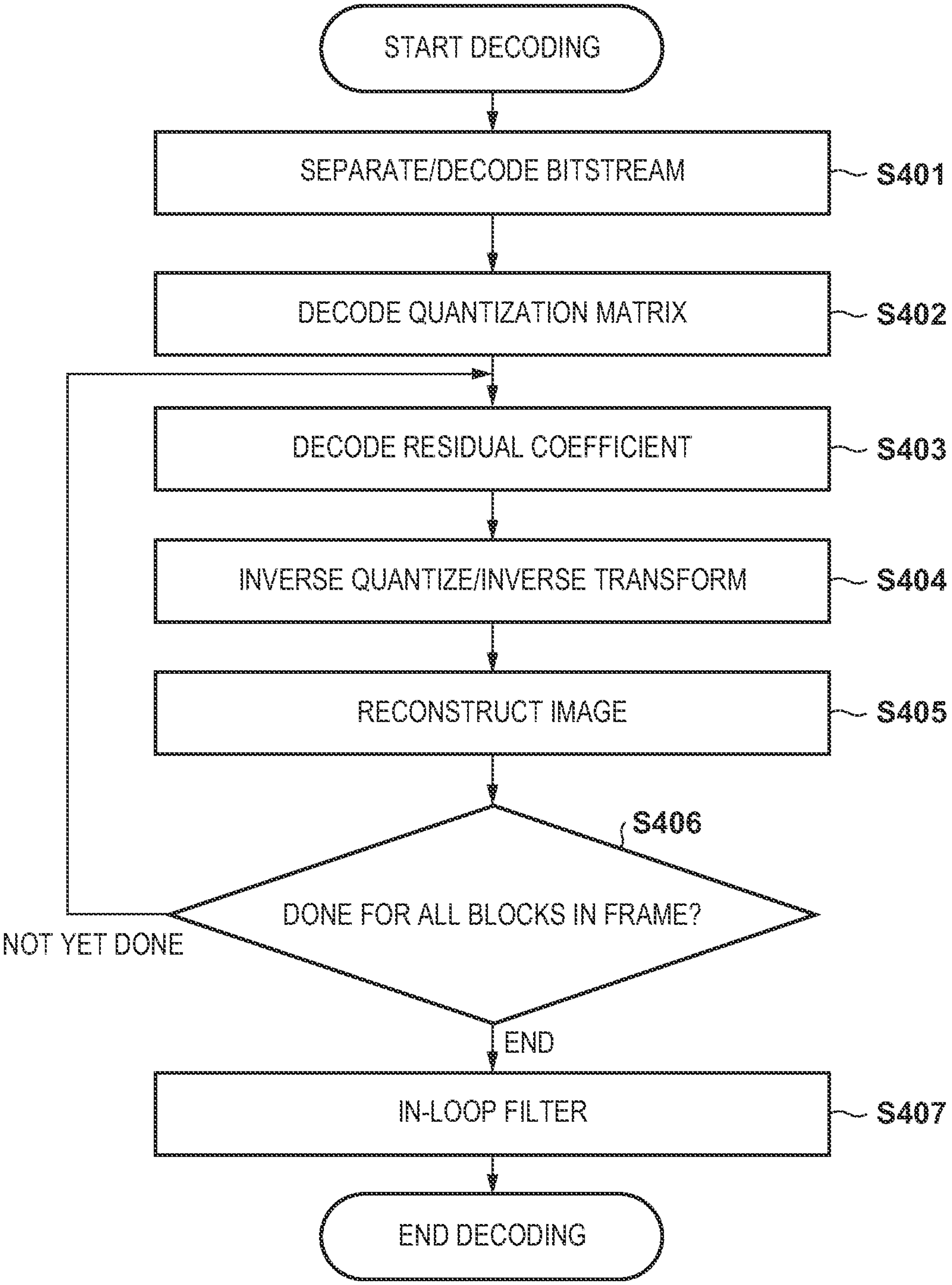

START DECODING
SEPARATE/DECODE BITSTREAM
S401
DECODE QUANTIZATION MATRIX
S402
DECODE RESIDUAL COEFFICIENT
S403
INVERSE QUANTIZE/INVERSE TRANSFORM
S404
RECONSTRUCT IMAGE
S405
S406
DONE FOR ALL BLOCKS IN FRAME?
NOT YET DONE
END
IN-LOOP FILTER
S407
END DECODING

FIG. 5

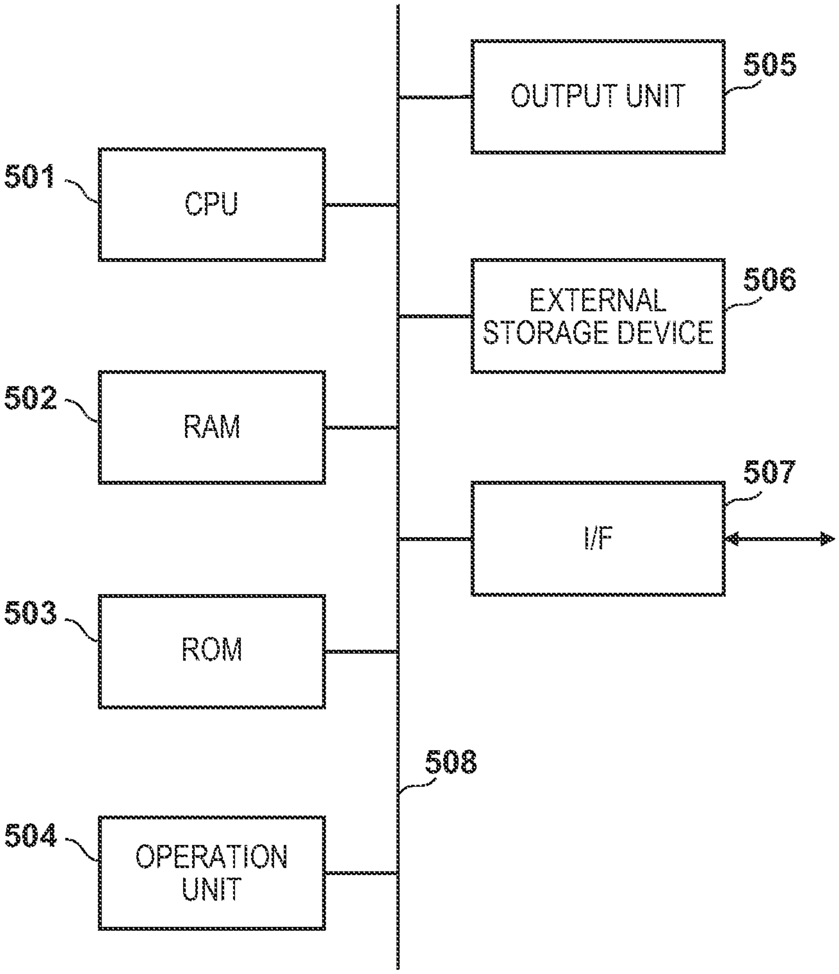

501
CPU
502
RAM
503
ROM
504
OPERATION UNIT
505
OUTPUT UNIT
506
EXTERNAL STORAGE DEVICE
507
I/F
508

FIG. 6A

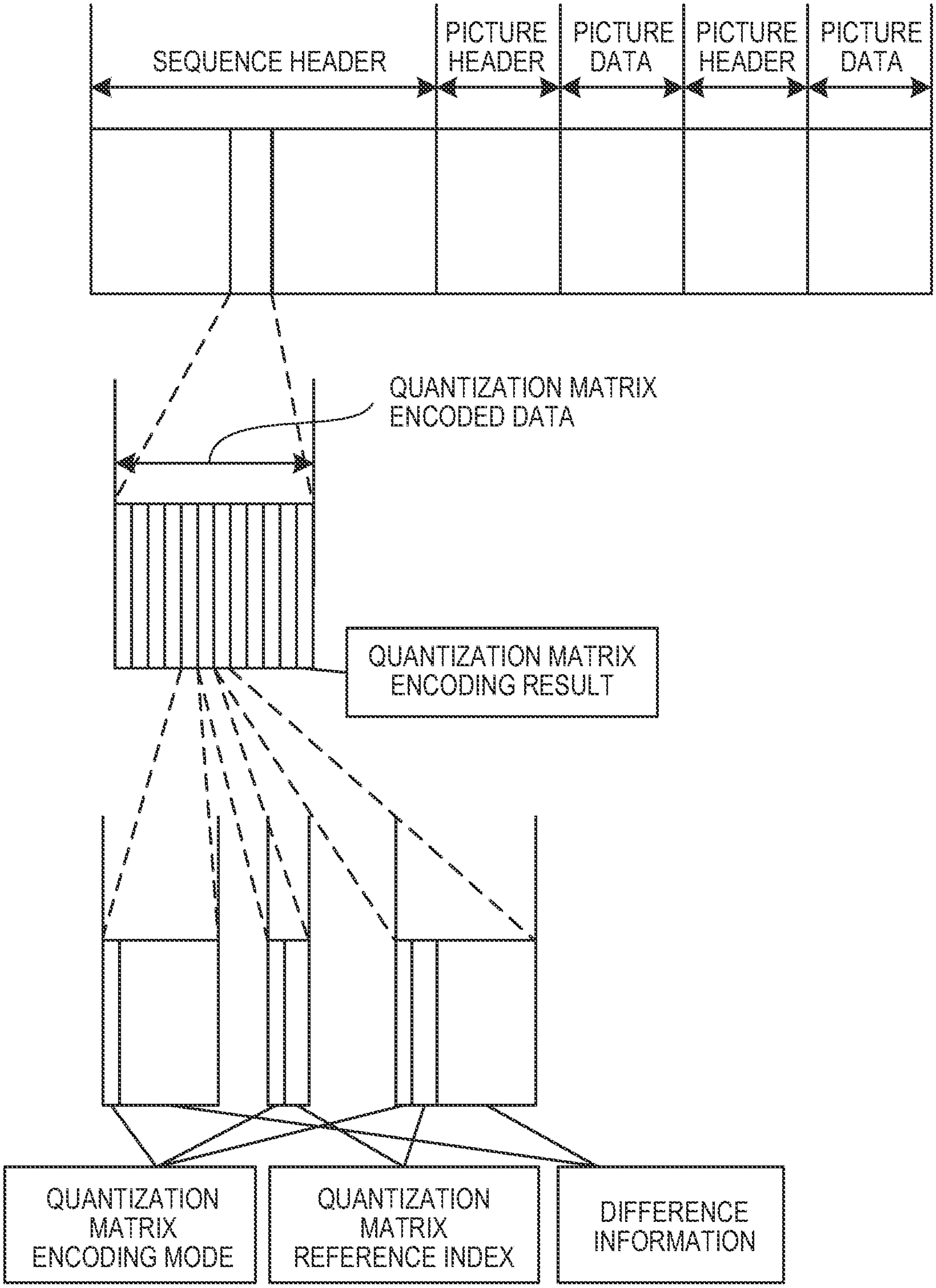

SEQUENCE HEADER
PICTURE HEADER
PICTURE DATA
PICTURE HEADER
PICTURE DATA
QUANTIZATION MATRIX ENCODED DATA
QUANTIZATION MATRIX ENCODING RESULT
QUANTIZATION MATRIX ENCODING MODE
QUANTIZATION MATRIX REFERENCE INDEX
DIFFERENCE INFORMATION

FIG. 6B

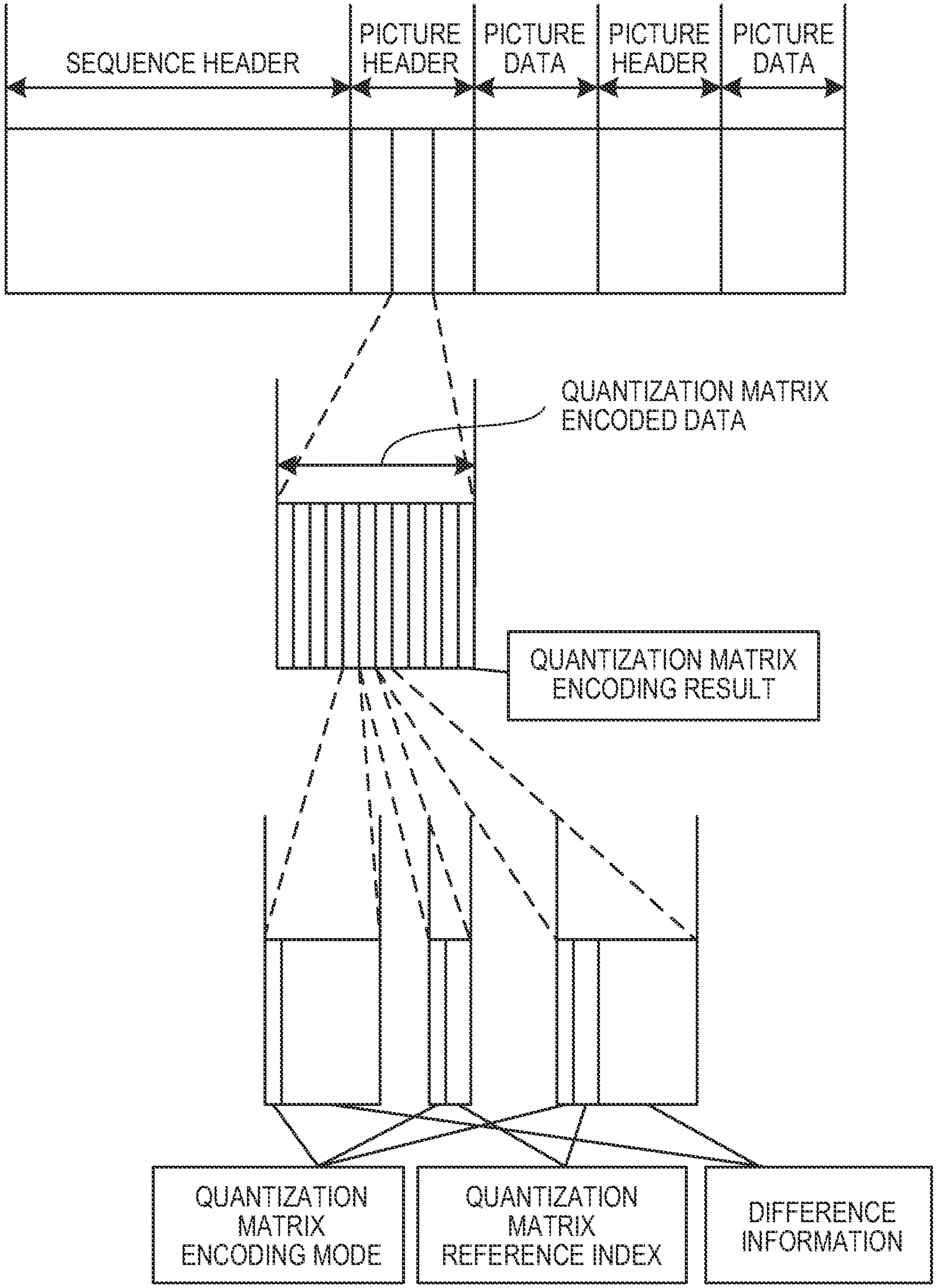

SEQUENCE HEADER
PICTURE HEADER
PICTURE DATA
PICTURE HEADER
PICTURE DATA
QUANTIZATION MATRIX ENCODED DATA
QUANTIZATION MATRIX ENCODING RESULT
QUANTIZATION MATRIX ENCODING MODE
QUANTIZATION MATRIX REFERENCE INDEX
DIFFERENCE INFORMATION

FIG. 7A

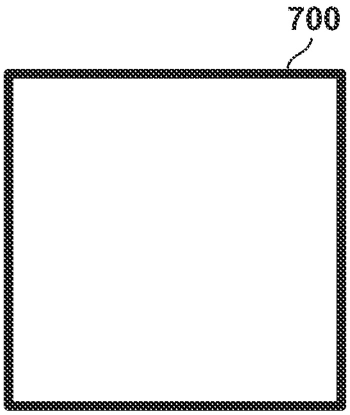


FIG. 7B

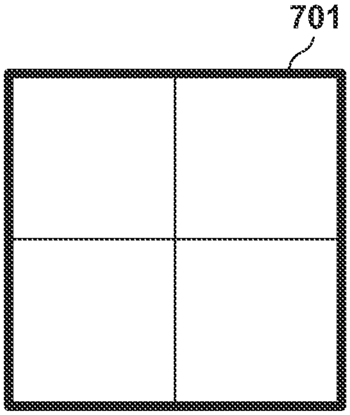


FIG. 7C

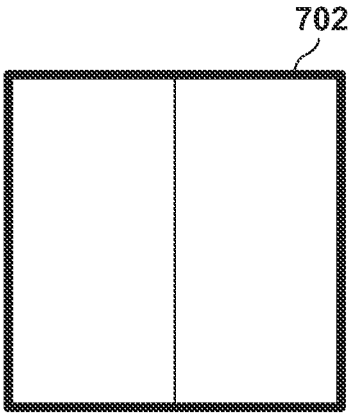


FIG. 7D

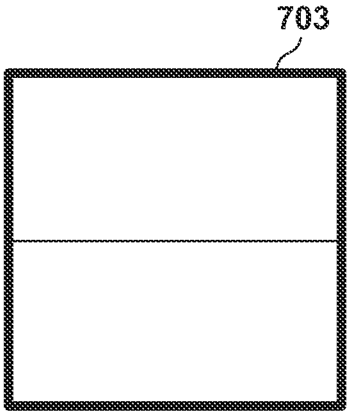


FIG. 7E

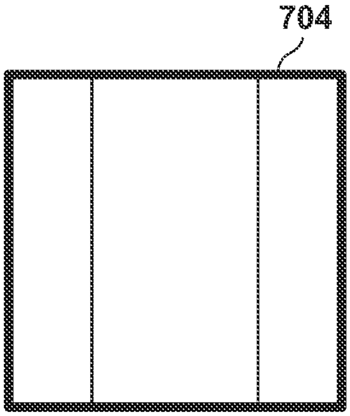


FIG. 7F

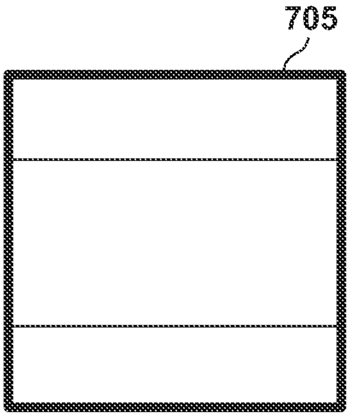


FIG. 8A

6	10	13	16	18	23	25	27
10	11	16	18	23	25	27	29
13	16	18	23	25	27	29	31
16	18	23	25	27	29	31	33
18	23	25	27	29	31	33	36
23	25	27	29	31	33	36	38
25	27	29	31	33	36	38	40
27	29	31	33	36	38	40	42

800

FIG. 8B

6	13	20	28
13	20	28	32
20	28	32	37
28	32	37	42

801

FIG. 8C

7	13	19	28
13	19	28	33
19	28	33	37
28	33	37	41

802

FIG. 8D

9	13	15	17	19	21	22	24
13	13	17	19	21	22	24	25
15	17	19	21	22	24	25	27
17	19	21	22	24	25	27	28
19	21	22	24	25	27	28	30
21	22	24	25	27	28	30	32
22	24	25	27	28	30	32	33
24	25	27	28	30	32	33	35

803

FIG. 8E

10	14	20	24
14	20	24	27
20	24	27	30
24	27	30	34

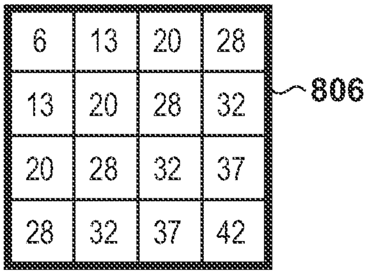
804

FIG. 8F

8	14	19	24
14	19	24	27
19	24	27	31
24	27	31	35

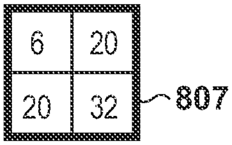
805

FIG. 8G



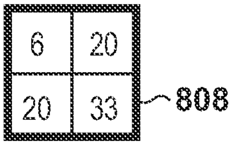
6	13	20	28
13	20	28	32
20	28	32	37
28	32	37	42

FIG. 8H



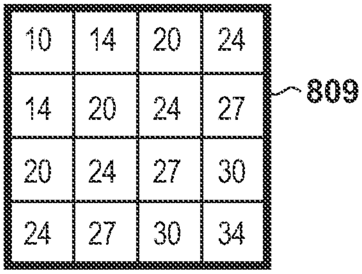
6	20
20	32

FIG. 8I



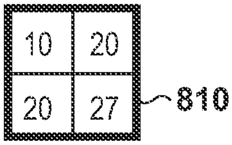
6	20
20	33

FIG. 8J



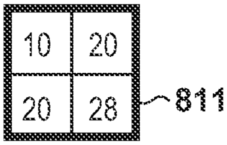
10	14	20	24
14	20	24	27
20	24	27	30
24	27	30	34

FIG. 8K



10	20
20	27

FIG. 8L



10	20
20	28

FIG. 9A

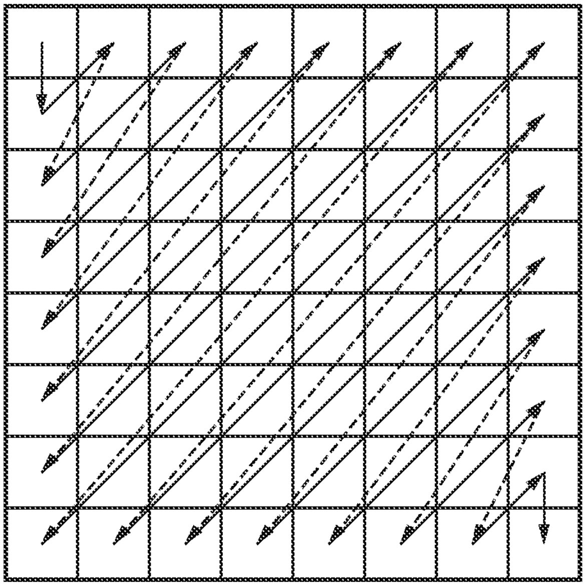


FIG. 9B

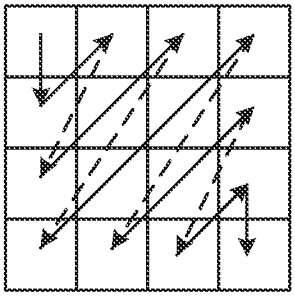


FIG. 9C

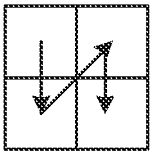
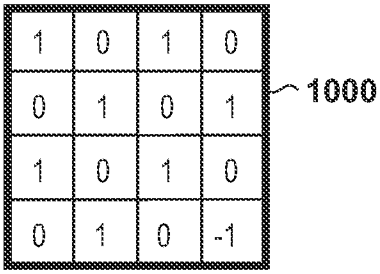
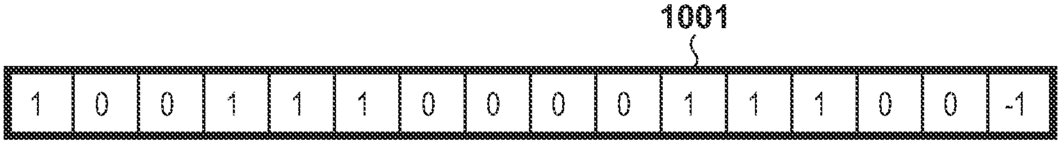


FIG. 10A



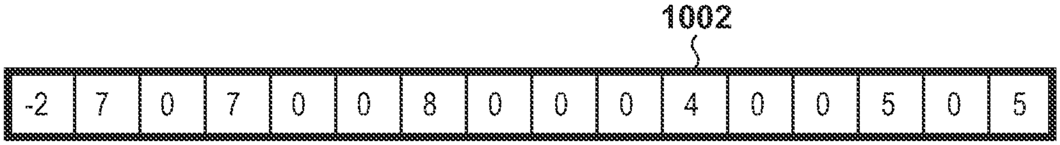
1	0	1	0
0	1	0	1
1	0	1	0
0	1	0	-1

FIG. 10B



1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	-1

FIG. 10C



-2	7	0	7	0	0	8	0	0	0	4	0	0	5	0	5

FIG. 11A

ENCODING TARGET VALUE	BINARY CODE
...	...
-5	0001011
-4	0001001
-3	00111
-2	00101
-1	011
0	1
1	010
2	00100
3	00110
4	0001000
5	0001010
...	...

FIG. 11B

ENCODING TARGET VALUE	BINARY CODE
...	...
-5	0001011
-4	0001001
-3	00111
-2	0010
-1	011
0	11
1	10
2	010
3	00110
4	0001000
5	0001010
...	...

FIG. 12

scaling_list_data( ) {	Descriptor
for(sizeId = 1; sizeId < 4; sizeId++)	
for(matrixId = 0; matrixId < 6; matrixId ++) {	

if(! (((sizeId = = 1) && (matrixId % 3 = = 0)) | |
                ((sizeId = = 3) && (matrixId % 3 != 0)))) {	

scaling_list_pred_mode_idx[sizeId][matrixId]	u(1)
if(scaling_list_pred_mode_idx[sizeId][matrixId] < 2) {	
scaling_list_pred_matrix_id_delta[sizeId][matrixId]	ue(v)
if(scaling_list_pred_mode_idx[sizeId][matrixId] == 1) {	
refMatrixId = matrixId – scaling_list_pred_matrix_id_delta - 1	
coefNum = (1 << (sizeId << 1))	
for(i = 0; i < coefNum; i++) {	
nextCoef = ScalingList[sizeId][refMatrixId][i]	
scaling_list_pred_delta	se(v)
nextCoef = (nextCoef + scaling_list_pred_delta + 256) % 256	
ScalingList[sizeId][matrixId][i] = nextCoef	
}	
} else {	
nextCoef = 8	
coefNum = (1 << (sizeId << 1))	
for(i = 0; i < coefNum; i++) {	
scaling_list_delta_coef	se(v)
nextCoef = (nextCoef + scaling_list_delta_coef + 256) % 256	
ScalingList[sizeId][matrixId][i] = nextCoef	
}	
}	
}	
}	
}	
}	

FIG. 13A

16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16

1300

FIG. 13B

16	16	16	16
16	16	16	16
16	16	16	16
16	16	16	16

1301

FIG. 13C

16	16
16	16

1302

FIG. 14

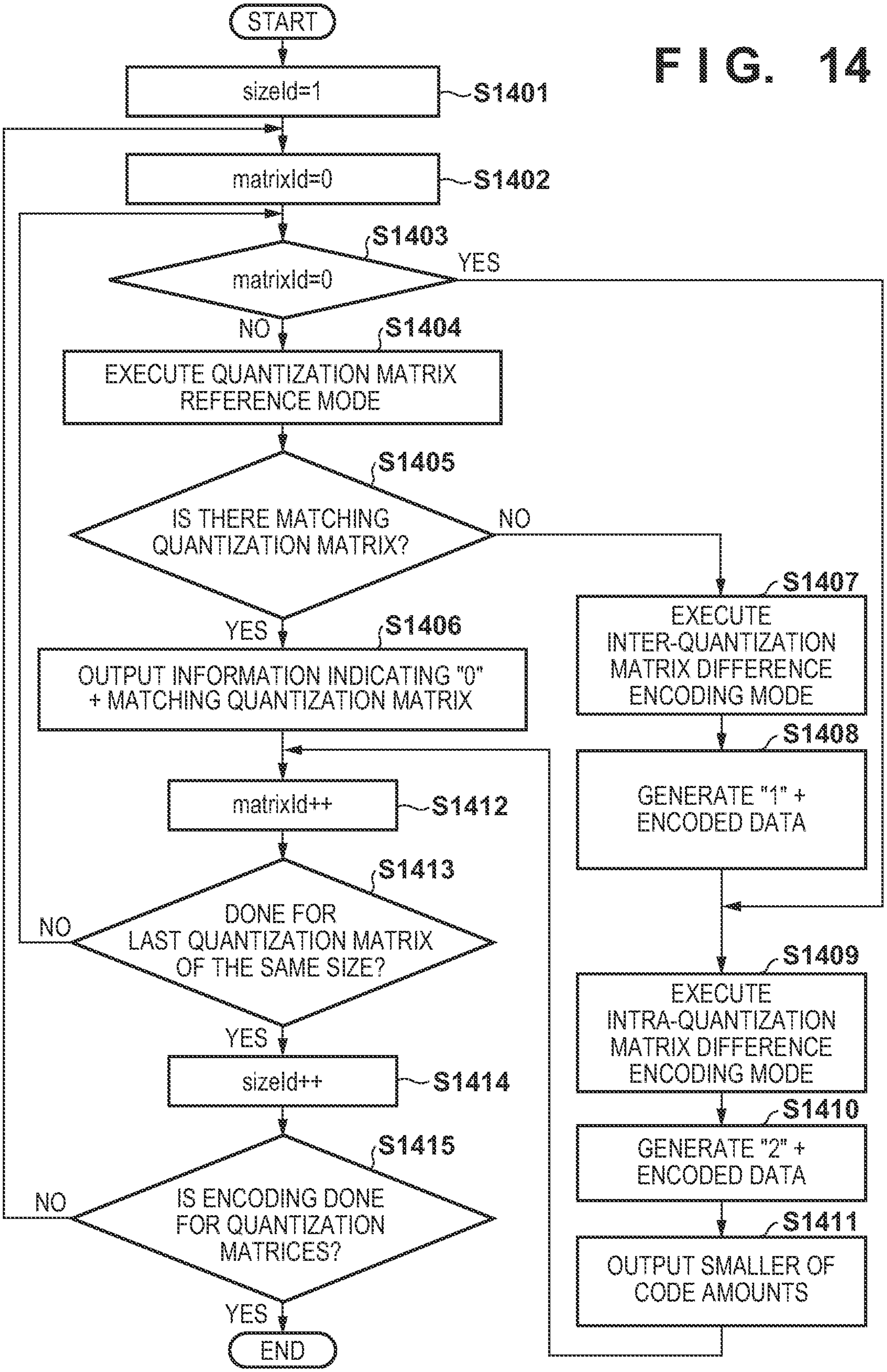

START
sizeId=1
S1401
matrixId=0
S1402
S1403
matrixId=0
YES
NO
S1404
EXECUTE QUANTIZATION MATRIX REFERENCE MODE
S1405
IS THERE MATCHING QUANTIZATION MATRIX?
NO
YES
S1406
OUTPUT INFORMATION INDICATING "0" + MATCHING QUANTIZATION MATRIX
S1407
EXECUTE INTER-QUANTIZATION MATRIX DIFFERENCE ENCODING MODE
S1408
GENERATE "1" + ENCODED DATA
matrixId++
S1412
S1413
DONE FOR LAST QUANTIZATION MATRIX OF THE SAME SIZE?
NO
YES
sizeId++
S1414
S1409
EXECUTE INTRA-QUANTIZATION MATRIX DIFFERENCE ENCODING MODE
S1410
GENERATE "2" + ENCODED DATA
S1411
OUTPUT SMALLER OF CODE AMOUNTS
S1415
IS ENCODING DONE FOR QUANTIZATION MATRICES?
NO
YES
END

IMAGE ENCODING APPARATUS, IMAGE DECODING APPARATUS, METHODS FOR THE SAME, AND NON-TRANSITORY COMPUTER-READABLE STORAGE MEDIUM FOR SUPPRESSING THE CODE AMOUNT OF QUANTIZATION MATRICES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of International Patent Application No. PCT/JP2020/030904, filed Aug. 14, 2020, which claims the benefit of Japanese Patent Application No. 2019-170810, filed Sep. 19, 2019, both of which are hereby incorporated by reference herein in their entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an image coding apparatus, an image decoding apparatus, methods for the same, and a non-transitory computer-readable storage medium.

Background Art

Known encoding methods for compressing and recording moving images include the HEVC (High Efficiency Video Coding) encoding method (hereinafter, simply referred to as HEVC). In order to improve encoding efficiency, HEVC employs basic blocks that are larger than conventional macroblocks (16×16 pixels). These large base blocks are called CTUs (Coding Tree Units), and are up to 64×64 pixels in size. CTUs are further divided into subblocks that serve as units for performing prediction and transformation.

Also, HEVC uses processing in which coefficients that have undergone orthogonal transformation (hereinafter, referred to as orthogonal transform coefficients), called quantization matrices, are weighted according to the frequency component. By further reducing data of the high frequency component whose deterioration is not readily visible to the human eye, it is possible to enhance compression efficiency while maintaining image quality. Patent Document 1 discloses a technology for encoding such quantization matrices.

In recent years, activities for carrying out international standardization of more efficient encoding methods as successors to HEVC have commenced. JVET (Joint Video Experts Team) was established between ISO/IEC and ITU-T, and standardization as the VVC (Versatile Video Coding) encoding method (hereinafter, VVC) is ongoing. In order to improve encoding efficiency, the basic blocks in VVC are up to 128×128 pixels in size, and rectangular subblock division is also being considered in addition to conventional square subblock division.

The introduction of quantization matrices to VVC similarly to HEVC is also been considered. Furthermore, with VVC, more types of subblock division than HEVC, including rectangular subblocks, are being considered. Since the distribution of orthogonal transform coefficients corresponding to each subblock division differs depending on the size and shape of the orthogonal transformation, it is desirable to define the optimal quantization matrix according to the size and shape of the subblocks. However, if individual quantization matrices are defined for all subblock shapes, the code amount of the quantization matrices will increase unnecessarily.

CITATION LIST

Patent Literature

PTL 1: Japanese Patent Laid-open No. 2013-38758

SUMMARY OF THE INVENTION

The present invention made been made in view of such problems, and provides a technology for suppressing the code amount of quantization matrices.

In order to solve this problem, an image encoding apparatus of the present invention is provided with the following configuration, for example. That is, the image encoding apparatus comprises

a quantization unit configured to quantize transform coefficients in a block in an image, using a first quantization matrix; and

an encoding unit configured to encode the first quantization matrix,

wherein

(a) in a case where a first mode is used to encode the first quantization matrix, the encoding unit encodes information indicating that the first quantization matrix is the same as a second quantization matrix which has already been encoded prior to encoding of the first quantization matrix,

(b) in a case where a second mode is used to encode the first quantization matrix, the encoding unit encodes a difference between an element of the first quantization matrix and an element of the second quantization matrix, and

(c) in a case where a third mode is used to encode the first quantization matrix, the encoding unit encodes a difference between an element and another element within the first quantization matrix,

wherein a code amount of information representing the first mode is used is less than a code amount of information representing that the second mode is used.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block configuration diagram of an image encoding apparatus of a first embodiment.

FIG. **2** is a block configuration diagram of an image decoding apparatus of the first embodiment.

FIG. **3** is a flowchart showing encoding processing in the image encoding apparatus of the first embodiment.

FIG. **4** is a flowchart showing decoding processing in the image decoding apparatus of the first embodiment.

FIG. **5** is a configuration diagram of computer hardware applied in a second embodiment.

FIG. **6**A is a diagram showing an example of the data structure of a bitstream generated by the image encoding apparatus of the first embodiment.

FIG. **6**B is a diagram showing an example of the data structure of a bitstream generated by the image encoding apparatus of the first embodiment.

FIG. **7**A is a diagram showing an example subblock division in the embodiments.

FIG. **7**B is a diagram showing an example subblock division in the embodiments.

FIG. **7**C is a diagram showing an example subblock division in the embodiments.

FIG. 7D is a diagram showing an example subblock division in the embodiments.

FIG. 7E is a diagram showing an example subblock division in the embodiments

FIG. 7F is a diagram showing an example subblock division in the embodiments.

FIG. 8A is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8B is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8C is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8D is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8E is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8F is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8G is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8H is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8I is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8J is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8K is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 8L is a diagram showing an example of a quantization matrix used in the embodiments.

FIG. 9A is a diagram showing a diagram showing a method for scanning elements of a quantization matrix used in the embodiments.

FIG. 9B is a diagram showing a diagram showing a method for scanning elements of a quantization matrix used in the embodiments.

FIG. 9C is a diagram showing a diagram showing a method for scanning elements of a quantization matrix used in the embodiments.

FIG. 10A is a diagram showing a diagram showing a difference value matrix of a quantization matrix generated in the embodiments.

FIG. 10B is a diagram showing a diagram showing a difference value matrix of a quantization matrix generated in the embodiments.

FIG. 10C is a diagram showing a diagram showing a difference value matrix of a quantization matrix generated in the embodiments.

FIG. 11A is a diagram showing an example of an encoding table used to encode difference values of a quantization matrix.

FIG. 11B is a diagram showing an example of an encoding table used to encode difference values of a quantization matrix.

FIG. 12 is a diagram showing an example of a syntax table for quantization matrices that is used in the embodiments.

FIG. 13A is a diagram showing an example of a reference quantization matrix that is used in the embodiments.

FIG. 13B is a diagram showing an example of a reference quantization matrix that is used in the embodiments.

FIG. 13C is a diagram showing an example of a reference quantization matrix that is used in the embodiments.

FIG. 14 is a flowchart showing a procedure for encoding a quantization matrix.

DESCRIPTION OF THE EMBODIMENTS

Hereinafter, embodiments will be described in detail with reference to the accompanying drawings. Note that the following embodiments do not limit the invention according to the patent claims. The embodiments describe a plurality of features, but not all of these features are essential to the invention, and the features may be discretionarily combined. Furthermore, constituent elements that are the same or similar are given the same reference numerals in the accompanying drawings, and redundant description thereof will be omitted.

First Embodiment

The embodiments describe a plurality of features, but not all of these features are essential to the invention, and the features may be discretionarily combined. Furthermore, in the accompanying drawings, constituent elements that are the same or similar are given the same reference numerals, and redundant description thereof will be omitted.

FIG. **1** is a block configuration diagram of an image encoding apparatus of a first embodiment. The image encoding apparatus has a control unit **150** that administers overall control of the apparatus. This control unit **150** has a CPU, a ROM for storing programs executed by the CPU, and a RAM that is utilized as a work area of the CPU. The image encoding apparatus has an input terminal **101**, a block division unit **102**, a quantization matrix holding unit **103**, a prediction unit **104**, a transformation/quantization unit **105**, an inverse quantization/inverse transformation unit **106**, an image reconstruction unit **107**, a frame memory **108**, an in-loop filter unit **109**, an encoding unit **110**, an integration encoding unit **111**, an output terminal **112**, and a quantization matrix encoding unit **113**.

The input terminal **101** inputs, in units of frames, image data for encoding generated by an image data source. The image data source is not limited in terms of type, being an image capturing apparatus, file server or storage medium storing image data for encoding or the like. The output terminal **112** outputs encoded data to an output destination device, and the output destination device is also not particularly limited, being a storage medium, file server or the like.

The block division unit **102** divides the images of input frames into a plurality of basic blocks, and outputs one basic block of each frame in order to the downstream prediction unit **104**.

The quantization matrix holding unit **103** generates a plurality of quantization matrices prior to encoding and holds the generated quantization matrices in an internal memory not shown. The method for generating quantization matrices is not particularly limited, and may involve quantization matrices being input by a user or computed from the characteristics of input images, or quantization matrices designated in advance as initial values being used. The quantization matrix holding unit **103** in the present embodiment generates and holds 8×8, 4×4 and 2×2 pixel-sized two-dimensional quantization matrices **800** to **811** compatible with orthogonal transformation an shown in FIGS. **8**A to **8**L. Here, quantization matrices **800**, **803**, **806** and **809** are quantization matrices for a luma component, and quantization matrices **801**, **802**, **804**, **805**, **807**, **808**, **810** and **811** are quantization matrices for two chroma components.

The prediction unit **104** determines subblock division for image data in basic block units, performs processing such as intra-prediction which is prediction within frames in subblock units and inter-prediction which is prediction between frames, and generates prediction image data. Furthermore, the prediction unit **104** computes and outputs prediction errors in pixel units from subblocks in the input image data and corresponding prediction image data. Also, the prediction unit **104** outputs information required in prediction, such as subblock division, prediction mode and motion vectors, together with the prediction errors. Henceforth, this information required in prediction will be referred to as prediction information.

The transformation/quantization unit **105** obtains orthogonal transform coefficients by performing, in subblock units, orthogonal transformation of prediction errors of the subblocks input from the prediction unit **104**. Furthermore, the transformation/quantization unit **105** performs quantization of the orthogonal transform coefficients using the quantization matrices stored in the quantization matrix holding unit **103**, and obtains residual coefficients (quantized orthogonal transform coefficients).

The inverse quantization/inverse transformation unit **106** inputs the residual coefficients from the transformation/quantization unit **105**, performs inverse quantization using the corresponding quantization matrices stored in the quantization matrix holding unit **103**, and reconstructs the orthogonal transform coefficients. The inverse quantization/inverse transformation unit **106** further performs inverse orthogonal transformation on the orthogonal transform coefficients to reconstruct the prediction errors.

The image reconstruction unit **107** generates prediction image data by referring to the frame memory **108** as appropriate, based on the prediction information output from the prediction unit **104**. The image reconstruction unit **107** generates reconstruction image data by adding the prediction errors input from the inverse quantization/inverse transformation unit **106** to the generated prediction image data, and stores the generated reconstruction image data in the frame memory **108**.

The in-loop filter **109** performs in-loop filtering such as deblocking filtering and sample adaptive offsetting on the reconstruction image stored in the frame memory **108**, and again stores the filtered image data in the frame memory **108**.

The encoding unit **110** encodes the residual coefficients output from the transformation/quantization unit **105** and the prediction information output from the prediction unit **104** to generate encoded data, and outputs the encoded data to the integration encoding unit **111**.

The quantization matrix encoding unit **113** encodes the quantization matrices (see FIGS. **8**A to **8**L) held in the quantization matrix holding unit **103**, generates quantization matrix encoded data, and outputs the quantization matrix encoded data to the integration encoding unit **111**.

The integration encoding unit **111** generates header encoded data including the quantization matrix encoded data output from the quantization matrix encoding unit **113**. The integration encoding unit **111** then positions the encoded data output from the encoding unit **110** to follow the header encoded data and forms a bitstream. The integration encoding unit **111** then outputs the formed bitstream via the output terminal **112**.

Here, the image encoding operation in the image encoding apparatus will be described below in more detail. In the present embodiment, a configuration is adopted in which moving image data having a 4:2:0 color format is input from the input terminal **101** in frame units at a predetermined frame rate (e.g., 30 frames/second), but a configuration may also be adopted in which still image data is input at one frame/minute. Also, in the present embodiment, for descriptive purposes, the block division unit **101** will be described as dividing the image data input from the input terminal **101** into a basic block of 8×8 pixels. That is, a basic block of 8×8 pixels includes a luma (Y) component of 8×8 pixels and chroma (Cb and Cr) components of 4×4 pixels. Note that this is to facilitate understanding, and the invention is not limited to the above numerical values (sizes).

Prior to encoding an image, generation and encoding of quantization matrices is performed.

The quantization matrix holding unit **103**, first, generates and holds quantization matrices. Specifically, the quantization matrix holding unit **103** generates quantization matrices, according to the size of the subblocks to be encoded and the type of prediction method. In the present embodiment, the quantization matrix holding unit **103** generates a quantization matrix corresponding to an 8×8 pixel base block that has is not been divided into subblocks shown in FIG. **7**A and a quantization matrix corresponding to 4×4 pixel subblocks obtained by performing quad-tree division on the basic block shown in FIG. **7**B. That is, the quantization matrix holding unit **103** generates 8×8 and 4×4 pixel-sized quantization matrices for the luma (Y) component, and 4×4 and 2×2 pixel-sized quantization matrix for the chroma (Cb and Cr) components. The quantization matrices that are generated are, however, not limited thereto, and quantization matrices corresponding to the shape of the subblocks such as 4×8 and 8×4 may be generated. The method of determining the elements constituting the quantization matrices is not particularly limited. For example, a predetermined initial value may be used, or the elements may be set individually. Also, the quantization matrices may be generated according to the characteristics of the images.

The quantization matrix holding unit **103** holds a plurality of types of quantization matrices generated in this way in an internal memory not shown. FIG. **8**A shows an 8×8 pixel-sized quantization matrix **800** for the Y component that uses intra-prediction. Also, FIG. **8**B shows a 4×4-pixel-sized quantization matrix **801** for the Cb component that likewise uses intra-prediction, and FIG. **8**C shows a 4×4-pixel-sized quantization matrix **802** for the Cr component that uses intra-prediction.

Similarly, FIG. **8**D shows an 8×8 pixel-sized quantization matrix **803** for the Y component that uses inter-prediction. Also, FIG. **8**E also shows a 4×4-pixel-sized quantization matrix **804** for the Cb component that uses inter-prediction, and FIG. **8**F shows a 4×4-pixel-sized quantization matrix **805** for the Cr component that uses inter-prediction.

Furthermore, FIG. **8**G shows a 4×4 pixel-sized quantization matrix **806** for the Y component that uses intra-prediction. Also, FIG. **8**H also shows a 2×2-pixel-sized quantization matrix **807** for the Cb component that uses intra-prediction, and FIG. **8**I shows a 2×2-pixel-sized quantization matrix **808** for the Cr component that uses intra-prediction.

Similarly, FIG. **8**J shows a 4×4 pixel-sized quantization matrix **809** for the Y component that uses inter-prediction. FIG. **8**K also shows a 2×2-pixel-sized quantization matrix **810** for the Cb component that uses inter-prediction, and FIG. **8**L shows a 2×2-pixel-sized quantization matrix **811** for the Cr component that uses inter-prediction.

In order to simplify description, configurations of 64 pixels (8×8), 16 pixels (4×4) and 4 pixels (2×2) are given, and each thick-framed square represents the elements constituting a quantization matrix. In the present embodiment, the 12 types of quantization matrices shown in FIGS. **8**A to **8**L are held in two-dimensional form, but the respective elements within the quantization matrices are naturally not limited thereto. Also, depending on the size of the subblocks, it is also possible to hold a plurality of quantization matrices for the same color component and the same prediction mode. Generally, since the quantization matrices realize quantization processing that depends on human visual characteristics, the elements of the low frequency component corresponding to the upper left portion of the quantization matrices are smaller, and the elements of the high frequency component corresponding to the lower right portion are larger, as shown in FIGS. **8**A to **8**L.

The quantization matrix encoding unit **113** reads out the two-dimensional quantization matrices held in the quantization matrix holding unit **106** in order, and determines the encoding mode of each quantization matrix to be used when encoding the quantization matrix. In the present embodiment, three types of quantization matrix encoding modes are used, namely, a "quantization matrix reference mode", an "inter-quantization matrix difference encoding mode", and an "intra-quantization matrix difference encoding mode". The quantization matrix encoding unit **113** determines, for each quantization matrix, a quantization matrix encoding mode that minimizes the data amount of the encoding result.

Here, the three types of quantization matrix encoding modes that are used by the quantization matrix encoding unit **113** of the present embodiment will be described in more detail.

The "quantization matrix reference mode" is a mode that is used when there is an encoded quantization matrix that matches the quantization matrix to be encoded. When this mode is used, the quantization matrix encoding unit **113** encodes a quantization matrix reference index, which is an identifier indicating the encoded quantization matrix matching the quantization matrix to be encoded, instead of encoding the elements of the quantization matrix to be encoded.

Next, the "inter-quantization matrix difference encoding mode" is a mode in which an encoded quantization matrix that approximates the quantization matrix to be encoded is selected, a difference value of each of the elements is computed, and the computed difference values are encoded. When this mode is selected, the quantization matrix encoding unit **113** encodes a quantization matrix reference index, which is an identifier indicating the quantization matrix to be referenced, and then encodes difference information which is a set of difference values of the respective elements.

Also, the "intra-quantization matrix difference encoding mode" is used when there are no encoded quantization matrices or when there are no encoded quantization matrices similar to the quantization matrix to be encoded. The quantization matrix encoding unit scans each element of the quantization matrix to be encoded, calculates the difference values between the elements, and encodes difference information which is a set of difference values.

FIG. **12** is a syntax table that is used in encoding the quantization matrix in the present embodiment. The encoding processing of the quantization matrices shown in FIGS. **8**A to **8**L of the present embodiment will be specifically described using this syntax table. First, the structure of the syntax table in FIG. **12** will be described. On the outermost side of the syntax table is a "for" loop for a parameter "sizeId". sizeId indicates the size of the quantization matrix, and quantization matrices of the same size are encoded in succession. sizeId=1 indicates a 2×2 pixel-sized quantization matrix. Similarly, sizeId=2 indicates a 4×4 pixel-sized quantization matrix, and sizeId=3 indicates an 8×8 pixel-sized quantization matrix.

The initial value of the sizeId in the for loop is "1", and defines that the value will be incremented by "1" every loop and the loop will be repeated as long as sizeId is less than 4. Therefore, in the present embodiment, this means that after the group of 2×2 pixel-sized quantization matrixes is encoded, the group of the 4×4 pixel-sized quantization matrices will be encoded, followed by the group of 8×8 pixel-sized quantization matrices. In VVC, orthogonal transformation from a minimum 2×2 pixel size to a 64×64 pixel size is used, and it is also possible to adopt a configuration in which for loops from a 2×2 pixel size whose sizeId is 1 to a 64×64 pixel size whose sizeId is 6 are set, and quantization matrices respectively corresponding thereto are encoded. However, in the present embodiment, the maximum orthogonal transformation size, that is, the maximum size of the subblocks is 8×8, and thus the upper limit value of a for loop is a sizeId of 3 corresponding to the 8×8 pixel size. This enables unnecessary quantization matrix encoding to be omitted and redundant code generation to be prevented, by setting the upper limit value of the for loop based on the maximum value of the orthogonal transformation size that is actually used.

Inside the for loop for sizeId, there is a for loop for a parameter matrixId. This matrixId is a parameter based on the prediction mode and color component, and a value of 0 means intra-prediction/Y component, 1 means intra-prediction/Cb component, and 2 means intra-prediction/Cr component. Similarly, a matrixId of 3 means inter-prediction/Y component, 4 means inter-prediction/Cb component, and 5 means inter-prediction/Cr component. That is, in a group of quantization matrices of the same size, the quantization matrices corresponding to intra-prediction are encoded first, and then the quantization matrices corresponding to inter-prediction are encoded. Furthermore, in a group of quantization matrices corresponding to the same prediction mode, the quantization matrices are encoded in the order Y component, Cb component, Cr component.

Taking the above encoding order of quantization matrices into consideration, the encoding order of the quantization matrices of FIGS. **8**A to **8**L is as follows.

First, the 2×2 pixel-sized quantization matrices of FIGS. **8**H, **8**I, **8**K and **8**L are encoded. Next, the 4×4 pixel-sized quantization matrices of FIGS. **8**G, **8**B, **8**C, **8**J, **8**E and **8**F are encoded. Finally, the 8×8 pixel-sized quantization matrices of FIGS. **8**A and **8**D are encoded.

In short, the above order of encoding involves encoding the quantization matrices in order of priority: (i) quantization matrix size, (ii) intra/inter type, and (iii) component (luma, chroma) type. Quantization matrix size is first in order of priority because encoding is performed with consideration for the correlation between quantization matrices.

Next, the procedure for encoding each quantization matrix will be described. First, the quantization matrix encoding unit **113** encodes the determined quantization matrix encoding mode. In the syntax table in FIG. **12**, scaling_list_pred_mode_idx corresponds to the quantization matrix encoding mode. In the present embodiment, the "quantization matrix reference mode" is used when the value thereof is 0, the "inter-quantization matrix difference encoding mode" is used when the value is 1, and the "intra-quantization matrix difference encoding mode" is used when the value is 2. Since the quantization matrix encoding mode is Golomb encoded, the code amount related to scaling_list_pred_mode_idx is smaller as this value decreases. That is, in the present embodiment, the code amount related to the matrix reference mode is the smallest, which is advantageous in that the code amount that arises is minimized when there is a large number of quantization matrices that are the same.

When using the quantization matrix reference mode, the quantization matrix encoding unit **113** encodes the quantization matrix reference index next. This corresponds to scaling_list_pred_matrix_id_delta in the syntax table in FIG. **12**. For example, the quantization matrix **801** in FIG.

8B is the same as the quantization matrix **806** in FIG. **8**G encoded most recently. Therefore, at the time of encoding the quantization matrix **801** in FIG. **8**B, the quantization matrix encoding unit **113** selects the quantization matrix reference mode, and encodes 0 indicating that the quantization matrix **801** is the quantization matrix encoded most recently as the quantization matrix reference index. This enables quantization matrices that are the same as the quantization matrix **806** in FIG. **8**G to be encoded. Note that when the quantization matrix encoded second most recently is used, the quantization matrix reference index will be "1".

On the other hand, when using the inter-quantization matrix difference encoding mode, the quantization matrix encoding unit **113** first encodes the quantization matrix reference index, similarly to when using the quantization matrix reference mode. Subsequently, the quantization matrix encoding unit **113** encodes difference information which is the difference between each element of the encoded reference quantization matrix defined by the quantization matrix reference index and the corresponding element of the quantization matrix to be encoded. This corresponds to scaling_list_pred_delta in the syntax table in FIG. **12**. For example, each element of the quantization matrix **802** in FIG. **8**C is similar to the corresponding element of the quantization matrix **801** in FIG. **8**B encoded most recently (in this example, the absolute value of the difference between corresponding elements is less than or equal to a predetermined value ("1" or less is illustrated). Therefore, at the time of encoding the quantization matrix **802**, the quantization matrix encoding unit **113** in FIG. **8**C selects the inter-quantization matrix difference encoding mode, and, first, encodes 0 indicating that the quantization matrix **802** is the quantization matrix encoded most recently as the quantization matrix reference index. Note that when encoding the difference from each element of the quantization matrix encoded second most recently, the quantization matrix reference index will be "1". Subsequently, the quantization matrix encoding unit **113** calculates the difference value between each element in FIG. **8**B, which is a reference quantization matrix, and the corresponding element of FIG. **8**C, which is the quantization matrix to be encoded, and computes a two-dimensional difference value matrix **1000** shown in FIG. **10**A. The quantization matrix encoding unit **113** then scans each difference value of the two-dimensional difference value matrix **1000** and arranges the difference values in a one-dimensional matrix. FIGS. **9**A to **9**C show the scanning method that is used in the present embodiment when a two-dimensional matrix in arranged one dimensionally, with FIGS. **9**A, **9**B and **9**C respectively corresponding to 8×8, 4×4 and 2×2 quantization matrices. Since the 4×4 quantization matrix is targeted here, the quantization matrix encoding unit **113** arranges the two-dimensional difference value matrix **1000** in FIG. **10**A in a one-dimensional difference value matrix **1001** shown in FIG. **10**B, using the scanning method shown in FIG. **9**B. The quantization matrix encoding unit **113** then encodes each difference value of the matrix **1001** in FIG. **10**B. Note that the absolute value of each difference value in FIG. **10**B is "1" or less, but there may be cases where the absolute value is greater than 1. By further acquiring the difference between adjacent difference values in consideration of such a case, it is possible to further reduce the code amount.

Also, when using the intra-quantization matrix difference encoding mode, the quantization matrix encoding unit **113** scans each element of the quantization matrix to be encoded, using one of FIGS. **9**A to **9**C, calculates the difference between two consecutive elements, and arranges the differences in a one-dimensional matrix. The quantization matrix encoding unit **113** then encodes each difference value arranged in the one-dimensional matrix as difference information. This corresponds to scaling_list_delta_coef in the syntax table in FIG. **12**. For example, since the quantization matrix **806** in FIG. **8**G is the first of the 4×4 pixel-sized quantization matrices to be encoded, there is no quantization matrix to reference using the aforementioned quantization matrix reference mode or inter-quantization matrix difference encoding mode. Therefore, at the time of encoding the quantization matrix **806** in FIG. **8**G, the quantization matrix encoding unit **113** necessarily selects the intra-quantization matrix difference encoding mode. Therefore, the quantization matrix encoding unit **113** scans the quantization matrix **806** in FIG. **8**G using FIG. **9**B, and computes, for every element, the difference from the immediately previous element in scanning order. The quantization matrix encoding unit **113** arranges the calculated differences in a one-dimensional matrix and obtains a one-dimensional difference value matrix **1002** shown in FIG. **10**C. Here, for example, the 4×4 pixel-sized quantization matrix in FIG. **8**G is scanned by the scanning method shown in FIG. **9**B, whereby an element 13 located immediately below the first element 6 located in the upper left is scanned, and +7 which is the difference is computed. Also, in encoding the first element of the quantization matrix (6 in the present embodiment), it is assumed that the difference from a predetermined initial value (e.g., 8) is calculated, but the present invention is naturally not limited thereto, and the difference from any value or the value of the first element itself may be used. The initial value need only be the same as the decoding apparatus. The quantization matrix encoding unit **113** then encodes each difference value in FIG. **10**C.

Here, the above processing for encoding the quantization matrices will be further described. The fifth "scaling_list_pred_mode_idx[sizeId][matrixId]" from the top in FIG. **12** is a parameter indicating the encoding mode of quantization matrices that depends on sizeId and matrixId. In computing this parameter, a quantization matrix (one of FIGS. **8**A to **8**L) specified by sizeId and matrixId is encoded in accordance with the above three encoding modes, and the encoding mode that minimizes the generated encoding is determined. Information (0 to 2 described above) specifying the determined encoding mode is then set as a parameter thereof.

The quantization matrix encoding unit **113** generates quantization matrix encoded data as an encoding result of each quantization matrix generated using the quantization matrix encoding modes in the manner described above. The quantization matrix encoding unit **113** of the present embodiment encodes the individual elements of a one-dimensional difference value matrix using the encoding table shown in FIG. **11**A by allocating a code word which is a binary code, and generates quantization matrix encoded data. Note that the encoding table is not limited thereto, and an encoding table shown in FIG. **11**B, for example, may be used. In this way, the quantization matrix encoding unit **113** outputs the generated quantization matrix encoded data to the downstream integration encoding unit **111**.

Returning to FIG. **1**, the integration encoding unit **111** integrates the quantization matrix encoded data into header information required in encoding the image data.

Subsequently, encoding of the image data is performed. Image data of one frame input from the input terminal **101** is supplied to the block division unit **102**.

The block division unit **102** divides the input image data of one frame into a plurality of basic blocks, and outputs image data in basic block units to the prediction unit **104**. In the present embodiment, image data in basic block units of 8×8 pixels will be supplied to the prediction unit **104**.

The prediction unit **104** executes prediction processing on the image data in basic block units input from the block division unit **102**. Specifically, the prediction unit **104** determines the subblock division for dividing the basic blocks into smaller subblocks, and further determines the prediction mode such as intra-prediction or inter-prediction in subblock units. Intra-prediction involves generating prediction pixels of the block to be encoded using encoded pixels located spatially around the block to be encoded, and also generating an intra-prediction mode indicating an intra-prediction method such as horizontal prediction, vertical prediction or DC prediction. Inter-prediction involves generating prediction pixels of the block to be encoded using encoded pixels of a frame that differs temporally from the block to be encoded, and also generating motion information indicating a reference frame, a motion vector or the like.

Subblock division methods will be described with reference to FIGS. **7**A to **7**F. The thick frames of blocks **700** to **705** in FIGS. **7**A to **7**F are the same 8×8 pixel size as the basic blocks. Each rectangle within the thick frame represents a subblock. FIG. **7**B represents an example of conventional square subblock division, with an 8×8 pixel basic block **701** being divided into four **484**-pixel subblocks. On the other hand, FIGS. **7**C to **7**F represent an example of rectangular subblock division. FIG. **7**C shows that a basic block **702** is divided into two 4×8 pixel-sized subblocks (long vertically). FIG. **7**D shows that a basic block **703** is divided into two 8×4 pixel-sized subblocks (long horizontally). FIGS. **7**E and **7**F show basic blocks **704** and **705** divided into three rectangular subblocks by a ratio of 1:2:1, although the division methods differ therebetween. In this way, encoding is performed using not only squares but also rectangular subblocks.

The present embodiment is described in terms of one of FIG. **7**A in which the 8×8 pixel-sized basic block is not divided into subblocks and FIG. **7**B in which the basic block is divided in four being used, but the subblock division method is not limited thereto. Tri-tree division such as FIGS. **7**E and **7**F or bi-tree division such as is shown in FIGS. **7**C and **7**D may be used. When subblock division other than FIGS. **7**A and **7**B are also used, quantization matrices corresponding to the subblocks that are used are generated in the quantization matrix holding unit **103**. Also, the generated quantization matrices will be encoded by the quantization matrix encoding unit **113**.

The prediction unit **104** generates prediction image data from the determined prediction mode and an encoded region stored in the frame memory **108**, and further computes prediction errors in pixel units from prediction image data corresponding to the subblock of interest in the input image data, and outputs the computed errors to the transformation/quantization unit **105**. Also, the prediction unit **104** outputs information such as subblock division and prediction mode to the encoding unit **110** and the image reconstruction unit **107** as prediction information.

The transformation/quantization unit **105** performs orthogonal transformation and quantization on the prediction errors input from the prediction unit **104** and generates residual coefficients. Specifically, the transformation/quantization unit **105**, first, performs orthogonal transformation processing that depends on the size of the subblocks on the prediction errors and generates orthogonal transform coefficients. The transformation/quantization unit **105** then quantizes the orthogonal transform coefficients using the quantization matrices stored in the quantization matrix holding unit **103** according to the prediction mode and color component, and generates residual coefficients. In the present embodiment, in the case where subblock division is not performed and the intra-prediction mode is used, the quantization matrix in FIG. **8**A is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**B is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**C for the orthogonal transform coefficients of the Cr component. Also, similarly, in the case where subblock division is not performed and the inter-prediction mode is used instead, the quantization matrix in FIG. **8**D is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**E is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**F is used for the orthogonal transform coefficients of the Cr component. On the other hand, in the case where the subblock division in FIG. **7**B is performed and the intra-prediction mode is used, the quantization matrix in FIG. **8**G is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**H is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**I is used for the orthogonal transform coefficients of the Cr component. Also, similarly, in the case where the subblock division in FIG. **7**B is performed and the inter-prediction mode is used instead, the quantization matrix in FIG. **8**J is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**K is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**L is used for the orthogonal transform coefficients of the Cr component. The quantization matrices used are, however, not limited thereto. The generated residual coefficients and chroma integration information are output to the encoding unit **110** and the inverse quantization/inverse transformation unit **106**.

The inverse quantization/inverse transformation unit **106** reconstructs the orthogonal transform coefficients by inverse quantization of the residual coefficients input from the transformation/quantization unit **105**, using the corresponding quantization matrices stored in the quantization matrix holding unit **103**. The inverse quantization/inverse transformation unit **106** further performs inverse orthogonal transformation on the reconstructed orthogonal transform coefficients to reconstruct the prediction errors. In the inverse quantization processing, the quantization matrices corresponding to the size and color component of the subblocks to be encoded are used, similarly to the transformation/quantization unit **105**. Specifically, the inverse quantization/inverse transformation unit **106** performs inverse quantization using the same quantization matrices used by the transformation/quantization unit **105**. That is, in the case where subblock division is not performed and the intra-prediction mode is used, the quantization matrix in FIG. **8**A is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**B is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**C is used for the orthogonal transform coefficients of the Cr component. Also, similarly, in the case where subblock division is not performed and the inter-prediction mode is used instead, the quantization matrix in FIG. **8**D is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**E is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**F is used for the orthogonal transform coefficients of the Cr component. On the other hand, in the case where the subblock division in FIG. **7**B is performed and the intra-prediction mode is used, the quantization matrix in FIG. **8**G is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**H is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**I is used for the orthogonal transform coefficients of the Cr component. Also, similarly, in the case where the subblock division in FIG. **7**B is performed and the inter-prediction mode is used instead, the quantization matrix in FIG. **8**J is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**K is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**L is used for the orthogonal transform coefficients of the Cr component.

The prediction errors reconstructed by performing inverse orthogonal transformation to the orthogonal transform coefficients thus reconstructed are output to the image reconstruction unit **107**.

The image reconstruction unit **107** reconstructs the prediction image with reference to the frame memory **108** as appropriate, based on the prediction information input from the prediction unit **104**. The image reconstruction unit **107** then generates reconstruction image data in subblock units, based on the reconstructed prediction image and the prediction errors of the subblocks reconstructed by the inverse quantization/inverse transformation unit **106**, and stores the generated reconstruction image data in the frame memory **108**.

The in-loop filter unit **109** reads out the reconstruction image data from the frame memory **108**, and performs in-loop filtering such as deblock filtering. The in-loop filter unit **109** then re-stores the filtered image data in the frame memory **108**.

The encoding unit **110** entropy encodes the residual coefficients and chroma integration information in subblock units generated by the transformation/quantization unit **105** and the prediction information input from the prediction unit **104**, and generate encoded data. While no particular method of entropy encoding is designated, methods such as Golomb coding, arithmetic coding and Huffman coding can be used. The encoding unit **110** outputs the generated encoded data to the integration encoding unit **111**.

The integration encoding unit **111** multiplexes the encoded data input from the encoding unit **110** and the like together with the above encoded data of the header to form a bitstream. The integration encoding unit **111** then outputs the formed bitstream externally (to a storage medium, network, etc.) from the output terminal **112**.

FIG. **6**A is an example of the data structure of the output bitstream in the present embodiment. The sequence header includes the encoded data of the quantization matrices and is constituted by the encoding results of the quantization matrices. The position where the encoded data of the quantization matrices is stored is, however, not limited thereto, and a configuration may also naturally be adopted in which the encoded data is arranged in a picture header portion such as is shown in FIG. **6**B or a header portion spanning a plurality of pictures. Also, when changing quantization matrices in a single sequence, updating is also possible by newly encoding quantization matrices. At this time, all of the quantization matrices may be overwritten, and it is also possible to adopt a configuration in which some of the quantization matrices are changed by specifying the size, prediction mode and color component of the quantization matrices corresponding to the quantization matrices to be overwritten.

FIG. **3** is a flowchart showing one frame of encoding processing of the control unit **150** in the image encoding apparatus of the embodiment.

First, prior to encoding the image, the control unit **150**, in step S**301**, controls the quantization matrix holding unit **103** to generate and hold two-dimensional quantization matrices. The quantization matrix holding unit **103** of the present embodiment is compatible with 8×8 to 2×2 pixel-sized blocks, and generates and holds quantization matrices that correspond to the respective color components and prediction modes shown in FIGS. **8**A to **8**L.

In step S**302**, the control unit **150** controls the quantization matrix encoding unit **113** to encode the quantization matrices generated and held in step S**301**. The specific operations of the quantization matrix encoding unit **113** here have been described and will thus be omitted. In the present embodiment, the control unit **150** controls the quantization matrix encoding unit **113** to perform encoding based on the syntax table in FIG. **12** on the quantization matrices **801** to **811** shown in FIGS. **8**A to **8**L and generate quantization matrix encoded data.

In step S**303**, the control unit **150** controls the integration encoding unit **111** to encode and output header information required in encoding the image data together with the generated quantization matrix encoded data.

In step S**304**, the control unit **150** controls the block division unit **102** to divide the input image in frame units into basic block units.

In step S**305**, the control unit **150** controls the prediction unit **104** to divide the image data in basic blocks generated in step S**304** into subblocks, execute prediction processing on each subblock, and generate prediction image data and prediction information such as subblock division information and prediction modes. Furthermore, the control unit **150** controls the prediction unit **104** to compute prediction errors from the input image data of the subblocks and the prediction image data.

In step S**306**, the control unit **150** controls the transformation/quantization unit **105** to perform orthogonal transformation on the prediction errors computed in step S**305**, and generate orthogonal transform coefficients. Furthermore, the control unit **150** controls the transformation/quantization unit **105** to perform quantization using the quantization matrices generated and held in step S**301**, and generate residual coefficients. In the present embodiment, the quantization matrices in FIGS. **8**A to **8**L are used according to the subblock size, the prediction mode and the color component.

In step S**307**, the control unit **150** controls the inverse quantization/inverse transformation unit **106** to perform inverse quantization on the residual coefficients generated in step S**306**, using the quantization matrices generated and held in step S**301**, and reconstruct the orthogonal transform coefficients. In this step, inverse quantization processing is performed using the same quantization matrices as used in step S**306**. Inverse orthogonal transformation is then performed on the reconstructed orthogonal transform coefficients and the prediction errors are reconstructed.

In step S**308**, the control unit **150** controls the image reconstruction unit **107** to reconstruct the prediction image based on the prediction information generated in step S**305**, reconstruct the image data from the reconstructed prediction image and the prediction errors generated in step S**307**, and store the reconstructed image data in the frame memory **108**.

In step S309, the control unit **150** controls the encoding unit **110** to perform encoding of the prediction information generated in step S305 and the residual coefficient generated in step S306, and generate encoded data. Also, the encoding unit **110** outputs the generated encoded data to the integration encoding unit **111**. The integration encoding unit **111** positions the encoded data from the encoding unit **110** to follow the header generated previously, and outputs the resultant data.

In step S310, the control unit **150** determines whether all the basic blocks within the frame of interest have been encoded. The control unit **150** advances to step S311 if it is determined that encoding has finished, and, if it is determined that there remain any basic blocks that have not been encoded, returns the processing to step S304 and continues encoding on the next basic block.

In step S311, the control unit **150** controls the in-loop filter unit **109** to perform in-loop filtering on the image data reconstructed in step S308 and generate a filtered image, and ends the processing.

In the above configuration and operations, the generated code amount of the quantization matrices can be suppressed, particularly by determining and encoding the quantization matrix encoding mode that minimizes the generated code amount of the quantization matrices in step S302.

Note that, in the present embodiment, it is only possible to reference quantization matrices of the same size in the quantization matrix reference mode and the inter-quantization matrix difference encoding mode, but a configuration may also be adopted in which it is possible to reference quantization matrices of different sizes using enlargement and reduction. For example, when encoding the quantization matrix **806** in FIG. **8**G, a configuration may also be adopted in which the quantization matrix **807** in FIG. **8**H is referenced and enlarged, and the difference values between the two quantization matrixes are encoded as difference information. It thereby becomes possible to further reduce the data amount of the quantization matrix that is initially encoded in each size.

Also, in the present embodiment, as shown in the syntax table in FIG. **12**, a configuration is adopted in which the quantization matrices are encoded in ascending order of size, but a configuration may also be adopted in which the quantization matrices are encoded in descending order of size. It is thereby possible to further reduce the data amount of the quantization matrices, particularly in the aforementioned case where reference between quantization matrices of different sizes is possible.

Furthermore, in the present embodiment, the reference target of the quantization matrices is limited to encoded quantization matrices, but a configuration can also be adopted in which the reference target is flat quantization matrices, such as is shown in FIGS. **13**A to **13**C, that are standard in the case where quantization matrices are not used. It is thereby possible to further reduce the data amount of quantization matrices, particularly in the case where the quantization matrices to be encoded approximate a flat quantization matrix.

FIG. **2** is a block configuration diagram of an image decoding apparatus that decodes encoded image data generated by the image encoding apparatus. Hereinafter, the configuration and operations related to decoding processing will be described with reference to FIG. **2**.

The image decoding apparatus has a control unit **250** that administers overall control of the apparatus. The control unit **250** has a CPU, a ROM for storing programs that are executed by the CPU, and a RAM that is utilized as a work area of the CPU. Also, the image decoding apparatus has an input terminal **201**, a separation and decoding unit **202**, a decoding unit **203**, an inverse quantization/inverse transformation unit **204**, an image reconstruction unit **205**, a frame memory **206**, an in-loop filter unit **207**, an output terminal **208** and a quantization matrix decoding unit **209**.

The input terminal **201** inputs encoded bitstreams, with the input source being a storage medium storing encoded streams, for example, but encoded bitstreams may be input from a network, and there is no limitation on the type of encoded bitstream.

The separation and decoding unit **202** separates information relating to decoding processing and encoded data relating coefficients from the bitstream, and decodes encoded data that is in the header portion of the bitstream. The separation and decoding unit **202** of the present embodiment separates quantization matrix encoded data and outputs the separated quantization matrix encoded data to the quantization matrix decoding unit **209**. Also, the separation and decoding unit **202** outputs encoded data of the image to the decoding unit **203**. That is, the separation and decoding unit **202** performs the reverse operation from the integration encoding unit **111** in FIG. **1**.

The quantization matrix decoding unit **209** reconstructs and holds quantization matrices by decoding the quantization matrix encoded data supplied from the separation and decoding unit **202**.

The decoding unit **203** decodes the encoded data of the image output from the separation and decoding unit **202** and reconstructs residual coefficients and prediction information in subblock units.

The inverse quantization/inverse transformation unit **204** reconstructs prediction errors by performing inverse quantization on the residual coefficients of the subblock of interest using the reconstructed quantization matrices, obtaining coefficients subjected to inverse quantization, and executing inverse orthogonal transformation, similarly to the inverse quantization/inverse transformation unit **106** in FIG. **1**.

The image reconstruction unit **205** generates prediction image data with reference to the frame memory **206** as appropriate based on the input prediction information. The image reconstruction unit **205** then generates reconstruction image data of the subblock of interest from the prediction errors reconstructed with the prediction image data and the inverse quantization/inverse transformation unit **204**, and stores the generated reconstruction image data in the frame memory **206**.

The in-loop filter unit **207** performs in-loop filtering such as deblocking filtering on the reconstruction image data stored in the frame memory **206**, and re-stores the filtered image data in the frame memory **206**, similarly to the in-loop filter unit **109** in FIG. **1**.

The output terminal **208** sequentially outputs frame images stored in the frame memory **206** externally. The output destination is generally a display device, but may be other devices.

Operations relating to decoding of an image by the image decoding apparatus of the above embodiment will now be described in more detail. In the present embodiment, encoded bitstreams are input in frame units.

In FIG. **2**, the bitstream for one frame input from the input terminal **201** is supplied to the separation and decoding unit **202**. The separation and decoding unit **202** separates information relating to the decoding processing and encoded data relating to coefficients from the bitstream, and decodes the encoded data that is in the header portion of the bitstream.

The separation and decoding unit **202** then supplies quantization matrix encoded data that is included in the header portion to the quantization matrix decoding unit **209**, and supplies encoded data of the image data to the decoding unit **203**. Specifically, the separation and decoding unit **202** first extracts quantization matrix encoded data from the sequence header of the bitstream shown in FIG. **6**A, and outputs the extracted quantization matrix encoded data to the quantization matrix decoding unit **209**. In the present embodiment, quantization matrix encoded data corresponding to the quantization matrices shown in FIGS. **8**A to **8**L is extracted and output. Next, encoded data in basic block units of the picture data is extracted and output to the decoding unit **203**.

The quantization matrix decoding unit **209**, first, decodes the input quantization matrix encoded data, and reconstructs the encoding result of each quantization matrix generated on the encoding side, based on the syntax table shown in FIG. **12**. As shown in FIG. **6**A, the encoding result of each quantization matrix is constituted by a quantization matrix encoding mode and data corresponding to the quantization matrix encoding mode.

For example, if the quantization matrix encoding mode, that is, scaling_list_pred_mode_idx in the syntax table in FIG. **12** is 0, this means that the quantization matrix was encoded in the quantization matrix reference mode. In this case, the quantization matrix encoding result is constituted by a quantization matrix encoding mode (0) and a quantization matrix reference index. For example, when decoding a 4×4 quantization matrix for intra-prediction and the Cb component, the quantization matrix decoding unit **209** first reconstructs the quantization matrix encoding mode=0, which means the quantization matrix reference mode. The quantization matrix decoding unit **209** then reconstructs the quantization matrix reference index. In the case where the quantization matrix reference index indicates that the quantization matrix to be referenced is the most recently decoded quantization matrix, the quantization matrix reference index will be 0. If the quantization matrix reference index is 1, the second most recently decoded quantization matrix is referenced. As a result of this information, the quantization matrix **209** knows that the 4×4 quantization matrix for intra-prediction and the Cb component is the same as the quantization matrix **806** in FIG. **8**G for intra-prediction and the Y component, and reconstructs the quantization matrix **801** in FIG. **8**B.

Also, if the quantization matrix encoding mode, that is, scaling_list_pred_mode_idx in the syntax table in FIG. **12** is 1, this means that the quantization matrix was encoded in the inter-quantization matrix difference encoding mode. In this case, the quantization matrix encoding result is constituted by a quantization matrix encoding mode (1), a quantization matrix reference index and difference information. For example, when decoding a 4×4 quantization matrix for intra-prediction and the Cr component, the quantization matrix decoding unit **209** first reconstructs quantization matrix encoding mode=1, which means the inter-quantization matrix difference encoding mode. The quantization matrix decoding unit **209** then reconstructs the quantization matrix reference index. In the case where the quantization matrix reference index indicates that the quantization matrix to be referenced is the most recently decoded quantization matrix, the quantization matrix reference index will be 0. If the quantization matrix reference index is 1, the second most recently decoded quantization matrix is referenced. Subsequently, the quantization matrix decoding unit **209** decodes the difference information, that is, scaling_list_pred_delta in the syntax table in FIG. **12**, for the number of elements in the quantization matrix, and reconstructs the one-dimensional difference value matrix **1001** shown in FIG. **10**B. The quantization matrix decoding unit **209** arranges the one-dimensional difference value matrix **1001** in FIG. **10**B two dimensionally using the scanning method in FIG. **9**B, and obtains the two-dimensional difference value matrix **1000** shown in FIG. **10**A. The quantization matrix decoding unit **209** then adds each difference value of the two-dimensional difference value matrix **1000** in FIG. **10**A to the respective element of the quantization matrix **801** to be referenced in FIG. **8**B, and reconstructs the quantization matrix **802** in FIG. **8**C.

On the other hand, if the quantization matrix encoding mode, that is, scaling_list_pred_mode_idx in the syntax table in FIG. **12** is 2, this means that the quantization matrix was encoded in the intra-quantization matrix difference encoding mode. In this case, the quantization matrix encoding result is constituted by a quantization matrix encoding mode (2) and difference information. For example, when decoding a 4×4 quantization matrix for intra-prediction and the Y component, the quantization matrix decoding unit **209**, first, reconstructs quantization matrix encoding mode=2, which means the intra-quantization matrix difference encoding mode. The quantization matrix decoding unit **209** then decodes the difference information, that is, scaling_list_delta_coef in the syntax table in FIG. **12** for the number of elements in the quantization matrix, and reconstructs the one-dimensional difference value matrix **1002** shown in FIG. **10**C. The quantization matrix decoding unit **209** is arranged two dimensionally using the scanning method in FIG. **9**B while adding each difference value within the one-dimensional difference value matrix **1002** in FIG. **10**C to the corresponding immediately previous element, and reconstructs the quantization matrix **806** in FIG. **8**G.

Note that, in the present embodiment, the encoding table in FIG. **11**A is used in decoding the difference information, but the encoding table in FIG. **11**B may also be used. In short, the same encoding table as on the encoding side may be used. The quantization matrix decoding unit **209** then holds the quantization matrices **800** to **811** thus reconstructed. Here, the operation is the reverse of the operation by the quantization matrix encoding unit **113** on the encoding side.

The decoding unit **203** decodes the encoded data supplied from the separation and decoding unit **202**, reconstructs the prediction information, and further reconstructs the residual coefficients. First, the decoding unit **203** reconstructs the prediction information and acquires the prediction mode that is used in the subblocks. The decoding unit **203** outputs the reconstructed residual coefficients to the inverse quantization/inverse transformation unit **204**, and outputs the reconstructed prediction information to the image reconstruction unit **205**.

The inverse quantization/inverse transformation unit **204** performs inverse quantization on the input residual coefficients using the quantization matrices reconstructed by the quantization matrix decoding unit **209** to generate orthogonal transform coefficients, and further performs inverse orthogonal transformation to reconstruct the prediction errors. The inverse quantization/inverse transformation unit **204** performs inverse quantization using the quantization matrices corresponding to the size and color component of the decoded subblocks, similarly to the inverse quantization/inverse transformation unit **106** on the encoding side. That is, in the case where subblock division is not performed and the intra-prediction mode is used, the quantization matrix in FIG. **8**A is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**B is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**C is used for the orthogonal transform coefficients of the Cr component. Also, similarly, in the case where subblock division is not performed and the inter-prediction mode is used instead, the quantization matrix in FIG. **8**D is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**E is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**F is used for the orthogonal transform coefficients of the Cr component. On the other hand, in the case where the subblock division in FIG. **7**B is performed and the intra-prediction mode is used, the quantization matrix in FIG. **8**G is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**H is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**I is used for the orthogonal transform coefficients of the Cr component. Also, similarly, in the case where the subblock division in FIG. **7**B is performed and the inter-prediction mode is used instead, the quantization matrix in FIG. **8**J is used for the orthogonal transform coefficients of the Y component, the quantization matrix in FIG. **8**K is used for the orthogonal transform coefficients of the Cb component, and the quantization matrix in FIG. **8**L is used for the orthogonal transform coefficients of the Cr component.

The prediction errors reconstructed by performing inverse orthogonal transformation on the orthogonal transform coefficients thus reconstructed are output to the image reconstruction unit **205**. The quantization matrices that are used are, however, not limited thereto, and may be the same as the quantization matrices used by the transformation/quantization unit **105** and the inverse quantization/inverse transformation unit **106** on the encoding side.

The image reconstruction unit **205** reconstructs the prediction image with reference to the frame memory **206** as appropriate, based on the prediction information input from the decoding unit **203**. With the image reconstruction unit **205** of the present embodiment, intra-prediction and inter-prediction are used, similarly to the prediction unit **104** on the encoding side. Since the specific prediction processing is similar to the prediction unit **104** on the encoding side, description thereof will be omitted. The image reconstruction unit **205** reconstructs image data from this prediction image and the prediction errors input from the inverse quantization/inverse transformation unit **204**, and stores the reconstructed image data in the frame memory **206**. The stored image data is used for reference during prediction.

The in-loop filter unit **207** reads out the reconstruction image from the frame memory **206** and performs in-loop filtering such as deblocking filtering, similarly to the in-loop filter unit **109** on the encoding side. The in-loop filter unit **207** then re-stores the filtered image in the frame memory **206**.

The reconstruction image stored in the frame memory **206** is ultimately output externally (typically to a display device) from the output terminal **208**.

FIG. **4** is a flowchart showing decoding processing by the control unit **250** in the image decoding apparatus according to the present embodiment.

First, in step S**401**, the control unit **250** controls the separation and decoding unit **202** to separate information relating to decoding processing and encoded data relating to coefficients from the bitstream, and decode the encoded data of the header portion. More specifically, the separation and decoding unit **202** supplies the encoded data of the quantization matrices to the quantization matrix decoding unit **209**, and supplies the encoded data of the image to the decoding unit **203**.

In step S**402**, the control unit **250** controls the quantization matrix decoding unit **209** to decode the quantization matrix encoded data reconstructed in step S**401** based on the syntax table in FIGS. **12**, and reconstruct and hold the quantization matrices **801** to **811** shown in FIGS. **8**A to **8**L. The specific operations of the quantization matrix decoding unit **209** referred to here have been described and will thus be omitted.

In step S**403**, the control unit **250** controls the decoding unit **203** to decode the encoded data separated in step S**401**, reconstruct the prediction information, and reconstruct the residual coefficients.

In step S**404**, the control unit **250** controls the inverse quantization/inverse transformation unit **204** to perform inverse quantization on the residual coefficients using the quantization matrices reconstructed in step S**402** and generate orthogonal transform coefficients. The inverse quantization/inverse transformation unit **204** further performs inverse orthogonal transformation and reconstructs the prediction errors. In the present embodiment, the quantization matrices that are used in the inverse quantization processing are determined according to characteristics of the subblocks to be decoded such as color component and size. That is, the inverse quantization/inverse transformation unit **204** performs inverse quantization using the quantization matrices in FIGS. **8**A to **8**L according to characteristics of the subblocks such as size, prediction mode and color component. The quantization matrices that are used are, however, not limited thereto, and may be the same as the quantization matrices used on the encoding side.

In step S**405**, the control unit **250** controls the image reconstruction unit **205** to reconstruct the image based on the prediction information generated in step S**403**. Specifically, the image reconstruction unit **205** reconstructs the prediction image with reference to the frame memory **206**, based on the prediction information. At this time, the image reconstruction unit **205** uses intra-prediction and inter-prediction, similarly to step S**305** on the encoding side. The image reconstruction unit **205** then reconstructs the image data from the reconstructed prediction image and the prediction errors generated in step S**404**, and stores the reconstruction image data in the frame memory **206**.

In step S**406**, the control unit **250** determines whether decoding of all the basic blocks in the frame of interest has ended, and advances to step S**407** if ended, and, if there are any basic blocks that have not been decoded, returns the processing to step S**403** in order to set the next basic block as the decoding target.

In step S**407**, the control unit **250** controls the in-loop filter unit **207** to perform in-loop filtering on the image data reconstructed in step S**405** and generate a filtered image, and ends the processing.

Due to the above configuration and operations, an encoded bitstream generated by the image encoding apparatus described above, that is, a bitstream encoded in an appropriate quantization matrix encoding mode and in which the generated code amount of the quantization matrix is suppressed, can be decoded.

Note that, in the present embodiment, it is only possible to reference quantization matrices of the same size in the quantization matrix reference mode and the inter-quantization matrix difference encoding mode, but a configuration may also be adopted in which it is possible to reference quantization matrices of different sizes using enlargement and reduction. For example, when decoding the quantization matrix **806** in FIG. **8**G, a configuration may also be adopted in which the quantization matrix **807** in FIG. **8**H is referenced and enlarged, the difference values between the two quantization matrixes are decoded as difference information, and the quantization matrix is reconstructed. It thereby becomes possible to also decode a bitstream in which the data amount of the quantization matrix that is initially encoded in each size has been further reduced.

Also, in the present embodiment, as shown in the syntax table in FIG. **12**, a configuration is adopted in which the quantization matrices are decoded in ascending order of size, but a configuration may also be adopted in which the quantization matrices are decoded in descending order of size. It is thereby possible to decode a bitstream in which the data amount of the quantization matrices has been further reduced, particularly in the aforementioned case where reference between quantization matrices of different sizes is possible.

Furthermore, in the present embodiment, the reference target of the quantization matrices is limited to encoded quantization matrices, but a configuration can also be adopted in which the reference target is flat quantization matrices **1300** to **1302**, such as is shown in FIGS. **13**A to **13**C, that are standard in the case where quantization matrices are not used. It is thereby possible to decode a bitstream in which the data amount of quantization matrices has been reduced, particularly in the case where the quantization matrices to be decoded approximate a flat quantization matrix.

Second Embodiment

The processing units included in the image encoding apparatus and the image decoding apparatus of the first embodiment are described as being constituted by hardware. However, the processing that is performed in each processing unit shown in the diagrams may be configured with a computer program.

FIG. **5** is a block diagram showing a configuration example of computer hardware applicable to the image encoding apparatus and decoding apparatus according to the above embodiment.

A CPU **501** performs overall control of the computer using computer programs and data that are stored in a RAM **502** and a ROM **503**, and executes the respective processing described above as performed by an image processing apparatus according to the above embodiment. That is, the CPU **501** functions as the respective processing units shown in FIGS. **1** and **2**.

The RAM **502** has an area for temporarily storing data acquired from outside via an external storage device **506** and an I/F (interface) **507**. Furthermore, the RAM **502** is also utilized as a work area that the CPU **501** uses when executing various processing. The RAM **502** can be allocated as frame memory or various other areas can be provided as appropriate, for example.

The ROM **503** stores setting data of the computer and a boot program. An operation unit **504** is constituted by a keyboard, a mouse and the like, and various instructions can be input to the CPU **501** by the user of the computer performing operations. A display unit **505** displays the results of processing by the CPU **501**. The display unit **505** is constituted by a liquid crystal display, for example.

The external storage device **506** is a large capacity information storage device typified by a hard disk drive device. The external storage device **506** stores an OS (operating system) and computer programs (application programs) for causing the CPU **501** to realize the functions of the various units shown in FIGS. **1** and **2**. Furthermore, the respective image data to be processed may be stored in the external storage device **506**.

The computer programs and data that are stored in the external storage device **506** are loaded to the RAM **502** as appropriate in accordance with control of the CPU **501** and undergo processing by the CPU **501**. Networks such as a LAN and the Internet and other devices such as a projection device and a display device can be connected to the I/F **507**, and the computer is able to acquire and send various information via the I/F **507**. Reference numeral **508** denotes a bus that connects the above units.

In the above configuration, when the apparatus is powered on, the CPU **501** executes the boot program stored in the ROM **503**, and loads the OS stored in the external storage device **506** to the RAM **502** and executes the loaded OS. The CPU **501**, under the control of the OS, then loads application programs related to encoding or decoding from the external storage device **506** to the RAM **502** and executes the loaded application programs. As a result, the CPU **501** functions as the respective processing units in FIG. **1** or FIG. **2**, and the apparatus functions as an image encoding apparatus or an image decoding apparatus.

Here, the processing for encoding quantization matrices in this second embodiment, that is, the processing corresponding to step **S302** in FIG. **3** will be described with reference to the flowchart in FIG. **14**.

Note that the order of the quantization matrices that are encoded is the same as the first embodiment, and is initially the 2×2 pixel-sized quantization matrices **807→808→810→811** in order, followed by the 4×4 pixel-sized quantization matrices **806→801→802→809→804→806** in order, and finally the 8×8 pixel-sized quantization matrix **800→803** in order.

Also, the following variables sizeId and matrixId have the same meaning as those shown in the first embodiment.

In other words, the variable sizeId is a variable indicating the size of the quantization matrix, and when the sizeId is "1", this indicates that the size of the quantization matrix to be encoded is 2×2 pixels. Furthermore, when the sizeId is "2", this indicates that the size of the quantization matrix to be encoded is 4×4 pixels. Also, when the sizeId is "3", this indicates that the size of the quantization matrix to be encoded is 8×8 pixels. Also, the variable matrixId indicates the order of quantization matrices of the same size. The quantization matrices to be encoded are identified by sizeId and matrixId.

For example, when sizeId=2 and matrixId=0, this indicates that the first 4×4 pixel-sized quantization matrix **806** is the quantization matrix to be encoded.

First, in step **S1401**, the CPU **501** sets the size of the quantization matrix to be encoded to 2×2 pixels by setting the variable sizeId to "1" as the initial value. Next, in step **S1402**, the CPU **501** sets the matrixId to "0" as the initial value. As a result, the quantization matrix **807** in FIG. **8**H is set as the quantization matrix of interest to be encoded in the case where this step **S1402** is first executed.

In step **S1403**, the CPU **501** determines whether the matrixId is "0". If matrixId is other than "0", there will be an encoded quantization matrix of the same size as the quantization matrix of interest. Therefore, the CPU **501** advances the processing to step **S1404** and performs search processing in the quantization matrix reference mode. In other words, the CPU **501** performs search processing as to whether there is an encoded quantization matrix of the same as the quantization matrix of interest.

In step S**1405**, the CPU **501** determines whether an encoded quantization matrix of the same as the quantization matrix of interest was found. If it is determined that such a quantization matrix was found, the CPU **501** advances the processing to step S**1406**, and outputs "0" and a value specifying the matching quantization matrix as encoded data of the quantization matrix of interest. Setting "0" at the start of the encoded data is equivalent to setting the parameter scaling_list_pred_mode_idx to "0". Also, with regard to the "value specifying the matching quantization matrix", the number "6" of 4×4 pixel-sized quantization matrices is greater than the number of quantization matrices of other sizes, and thus the bit number allocated to the value specifying that quantization matrix need only be "3". On the other hand, if it is determined that such a quantization matrix was not found, the CPU **501** advances the processing to step S**1407**.

If it is determined in step S**1403** that the matrixId is "0", the CPU **501** advances the processing to step S**1409**.

In this step S**1407**, the CPU **501** executes the inter-quantization matrix difference encoding mode for the quantization matrix of interest. Then, in step S**1408**, the CPU **501** obtains "1" and the encoded data generated in the inter-quantization matrix difference encoding mode. Setting "1" at the start of the encoded data is equivalent to setting the parameter scaling_list_pred_mode_idx to "1". A configuration may also be adopted in which information indicating the order of the quantization matrix that is the same as the quantization matrix of interest is output following the value "1" set at the start of the encoded data, and difference encoded data is output thereafter.

Next, in step S**1409**, the CPU **501** executes the intra-quantization matrix difference encoding mode for the quantization matrix of interest. Then, in step S**1410**, the CPU **501** obtains "2" and encoded data generated in the inter-quantization matrix difference encoding mode. Setting "2" at the start of the encoded data is equivalent to setting the return value of scaling_list_pred_mode_idx to "2".

Then, in step S**1411**, the CPU **501** outputs the smaller of the encoded data generated in step S**1408** and step S**1410** as encoded data of the quantization matrix of interest. Note that, in the case of branching from step S**1403** to step S**1409**, the encoded data generated in the inter-quantization matrix difference encoding mode in step S**1409** is output.

In step S**1412**, the CPU **501** increases the variable matrixId by "1". Then, in step S**1413**, the CPU **501** determines whether all the quantization matrices of the same size as the quantization matrix of interest have been encoded, based on the variables sizeId and matrixId. If the determination result of step S**1413** is "No", the CPU **501** advances the processing to step S**1403** and repeats the above processing.

Also, if the determination result of step S**1413** is "Yes", the CPU **501** increases sizeId by "1". Then, in step S**1415**, the CPU **501** determines whether the quantization matrices of all the sizes have been encoded, based on the variables sizeId and matrixId. If the determination result of step S**1415** is "No", there are quantization matrices of a size that have not been encoded, and thus the CPU returns the processing to step S**1402**. Also, if the determination result of step S**1415** is "Yes", this processing (step S**302** in FIG. **3**) is ended.

Note that, in the case where the processing advances to step S**1406**, it is assured that the encoded data generated in the quantization matrix reference mode will be reduced, and thus comparison with the encoded data generated in other modes is omitted, but naturally such comparison may be performed.

According to the present invention, it is possible to improve the encoding efficiency of image data by suppressing the code amount of quantization matrices more than before.

Other Embodiments

Embodiment(s) of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-transitory computer-readable storage medium') to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)™), a flash memory device, a memory card, and the like.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

Industrial Applicability

The present invention is used in encoding apparatuses/decoding apparatuses that encode/decode still images/moving images. In particular, the invention can be applied to encoding methods and decoding methods that use quantization matrices.

The invention claimed is:

1. An image encoding apparatus comprising:

a quantization unit configured to quantize transform coefficients in a block in an image, using a first quantization matrix; and

an encoding unit configured to encode the first quantization matrix,

wherein

(a) in a case where a first mode is used to encode the first quantization matrix, the encoding unit encodes, into a scaling list data syntax structure, information indicating that the first quantization matrix is the same as a second quantization matrix to be referenced, and encodes, into the scaling list data syntax structure, information for specifying the second quantization matrix,

(b) in a case where a second mode is used to encode the first quantization matrix, the encoding unit encodes, into the scaling list data syntax structure, the information for specifying the second quantization matrix, and encodes, into the scaling list data syntax structure, information for deriving a difference between an element of the first quantization matrix and an element of the second quantization matrix, and

(c) in a case where a third mode is used to encode the first quantization matrix, the encoding unit encodes a difference between an element and another element within the first quantization matrix,

wherein a code amount of information representing that the first mode is used is less than a code amount of information representing that the second mode is used,

wherein the code amount of information representing that the first mode is used is not greater than a code amount of information representing that the third mode is used, and

wherein a size of the second quantization matrix can only be 2×2, 4×4, or 8×8.

2. The image encoding apparatus according to claim **1**, wherein types of components of the blocks include a luma component and two chroma components, and transform coefficients of each component are quantized using the first quantization matrix corresponding to the component.

3. An image decoding apparatus comprising:

a decoding unit configured to decode a first quantization matrix; and

an inverse quantization unit configured to perform inverse quantization on residual coefficients, using the first quantization matrix,

wherein the decoding unit decodes, from a scaling list data syntax structure in a bitstream, first information representing a mode of decoding the first quantization matrix,

wherein (a) in a case where the first information decoded by the decoding unit represents that a first mode is used, the decoding unit decodes, from the scaling list data syntax structure, second information for specifying a second quantization matrix to be referenced and decodes the first quantization matrix by determining that the first quantization matrix is the same as the second quantization matrix specified based on the second information,

(b) in a case where the first information decoded by the decoding unit represents that a second mode is used, the decoding unit decodes, from the scaling list data syntax structure, the second information for specifying the second quantization matrix and decodes the first quantization matrix by using a difference between an element of the first quantization matrix and an element of the second quantization matrix specified based on the second information, and

(c) in a case where the first information decoded by the decoding unit represents that a third mode is used, the decoding unit decodes the first quantization matrix by using a difference between an element and another element within the first quantization matrix,

wherein a code amount of the first information representing that the first mode is used is less than a code amount of the first information representing that the second mode is used,

wherein the code amount of the first information representing that the first mode is used is not greater than a code amount of the first information representing that the third mode is used, and

wherein a size of the second quantization matrix can only be 2×2, 4×4, or 8×8.

4. An encoding method comprising:

quantizing transform coefficients in a block in an image, using a first quantization matrix; and

encoding the first quantization matrix, wherein

(a) in a case where a first mode is used to encode the first quantization matrix, the encoding encodes, into a scaling list data syntax structure, information indicating that the first quantization matrix is the same as a second quantization matrix to be referenced, and encodes, into the scaling list data syntax structure, information for specifying the second quantization matrix,

(b) in a case where a second mode is used to encode the first quantization matrix, the encoding encodes, into the scaling list data syntax structure, the information for specifying the second quantization matrix, and encodes, into the scaling list data syntax structure, information for deriving a difference between an element of the first quantization matrix and an element of the second quantization matrix, and

(c) in a case where a third mode is used to encode the first quantization matrix, the encoding encodes a difference between an element and another element within the first quantization matrix,

wherein a code amount of information representing that the first mode is used is less than a code amount of information representing that the second mode is used,

wherein the code amount of information representing that the first mode is used is not greater than a code amount of information representing that the third mode is used, and

wherein a size of the second quantization matrix can only be 2×2, 4×4, or 8×8.

5. A decoding method comprising:

decoding a first quantization matrix; and

performing inverse quantization on residual coefficients, using the first quantization matrix,

wherein the decoding decodes, from a scaling list data syntax structure in a bitstream, first information representing a mode of decoding the first quantization matrix,

wherein (a) in a case where the first information decoded in the decoding represents that a first mode is used, the decoding decodes, from the scaling list data syntax structure, second information for specifying a second quantization matrix to be referenced and decodes the first quantization matrix by determining that the first quantization matrix is the same as the second quantization matrix specified based on the second information,

(b) in a case where the first information decoded in the decoding represents that a second mode is used, the decoding decodes, from the scaling list data syntax structure, the second information for specifying the second quantization matrix and decodes the first quantization matrix by using a difference between an element of the first quantization matrix and an element of the second quantization matrix specified based on the second information, and

(c) in a case where the first information decoded in the decoding represents that a third mode is used, the decoding decodes the first quantization matrix by using a difference between an element and another element within the first quantization matrix,

wherein a code amount of the first information representing that the first mode is used is less than a code amount of the first information representing that the second mode is used,

wherein the code amount of the first information representing that the first mode is used is not greater than a code amount of the first information representing that the third mode is used, and

wherein a size of the second quantization matrix can only be 2×2, 4×4, or 8×8.

6. A non-transitory computer-readable storage medium storing a program which, when read and executed by a computer, causes the computer to executes the steps of an encoding method, the encoding method comprising:

quantizing transform coefficients in a block in an image, using a first quantization matrix; and

encoding the first quantization matrix, wherein

(a) in a case where a first mode is used to encode the first quantization matrix, the encoding encodes, into a scaling list data syntax structure, information indicating that the first quantization matrix is the same as a second quantization matrix to be referenced, and encodes, into the scaling list data syntax structure, information for specifying the second quantization matrix,

(b) in a case where a second mode is used to encode the first quantization matrix, the encoding encodes, into the scaling list data syntax structure, the information for specifying the second quantization matrix, and encodes, into the scaling list data syntax structure, information for deriving a difference between an element of the first quantization matrix and an element of the second quantization matrix, and

(c) in a case where a third mode is used to encode the first quantization matrix, the encoding encodes a difference between an element and another element within the first quantization matrix,

wherein a code amount of information representing that the first mode is used is less than a code amount of information representing that the second mode is used,

wherein the code amount of information representing that the first mode is used is not greater than a code amount of information representing that the third mode is used, and

wherein a size of the second quantization matrix can only be 2×2, 4×4, or 8×8.

7. A non-transitory computer-readable storage medium storing a program which, when read and executed by a computer, causes the computer to executes the steps of a decoding method, the decoding method comprising:

decoding a first quantization matrix; and

performing inverse quantization on residual coefficients, using the first quantization matrix,

wherein the decoding decodes, from a scaling list data syntax structure in a bitstream, first information representing a mode of decoding the first quantization matrix,

wherein (a) in a case where the first information decoded in the decoding represents that a first mode is used, the decoding decodes, from the scaling list data syntax structure, second information for specifying a second quantization matrix to be referenced and decodes the first quantization matrix by determining that the first quantization matrix is the same as the second quantization matrix specified based on the second information,

(b) in a case where the first information decoded in the decoding represents that a second mode is used, the decoding decodes, from the scaling list data syntax structure, the second information for specifying the second quantization matrix and decodes the first quantization matrix by using a difference between an element of the first quantization matrix and an element of the second quantization matrix specified based on the second information, and

(c) in a case where the first information decoded in the decoding represents that a third mode is used, the decoding decodes the first quantization matrix by using a difference between an element and another element within the first quantization matrix,

wherein a code amount of the first information representing that the first mode is used is less than a code amount of the first information representing that the second mode is used,

wherein the code amount of the first information representing that the first mode is used is not greater than a code amount of the first information representing that the third mode is used, and wherein a size of the second quantization matrix can only be 2×2, 4×4, or 8×8.

8. The image encoding apparatus according to claim **1**, wherein the second quantization matrix is a quantization matrix which has already been encoded or a default quantization matrix all elements of which are **16**.

9. The image encoding apparatus according to claim **1**, wherein the encoding unit encodes a plurality of quantization matrixes including the first quantization matrix and the second quantization matrix, each one of the plurality of quantization matrixes is encoded using one of the first mode, the second mode, and the third mode, and the first information is encoded for each one of the plurality of quantization matrixes, wherein the encoding unit:

firstly encodes the first information for a quantization matrix having a size of 2×2;

encodes the first information for a quantization matrix having a size of 4×4 after the first information is encoded for each one of quantization matrixes having the size of 2×2; and

encodes the first information for a quantization matrix having a size of 8×8 after the first information is encoded for each one of quantization matrixes having the size of 4×4.

10. The image decoding apparatus according to claim **3**, wherein the second quantization matrix is a quantization matrix which has already been decoded or a default quantization matrix all elements of which are 16.

11. The image decoding apparatus according to claim **3**, wherein the decoding unit decodes a plurality of quantization matrixes including the first quantization matrix and the second quantization matrix, each one of the plurality of quantization matrixes is decoded using one of the first mode, the second mode, and the third mode, the first information is decoded for each one of the plurality of quantization matrixes, wherein the decoding unit:

firstly decodes the first information for a quantization matrix having a size of 2×2;

decodes the first information for a quantization matrix having a size of 4×4 after the first information is decoded for each one of quantization matrixes having the size of 2×2; and decodes the first information for a quantization matrix having a size of 8×8 after the first information is decoded for each one of quantization matrixes having the size of 4×4.

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